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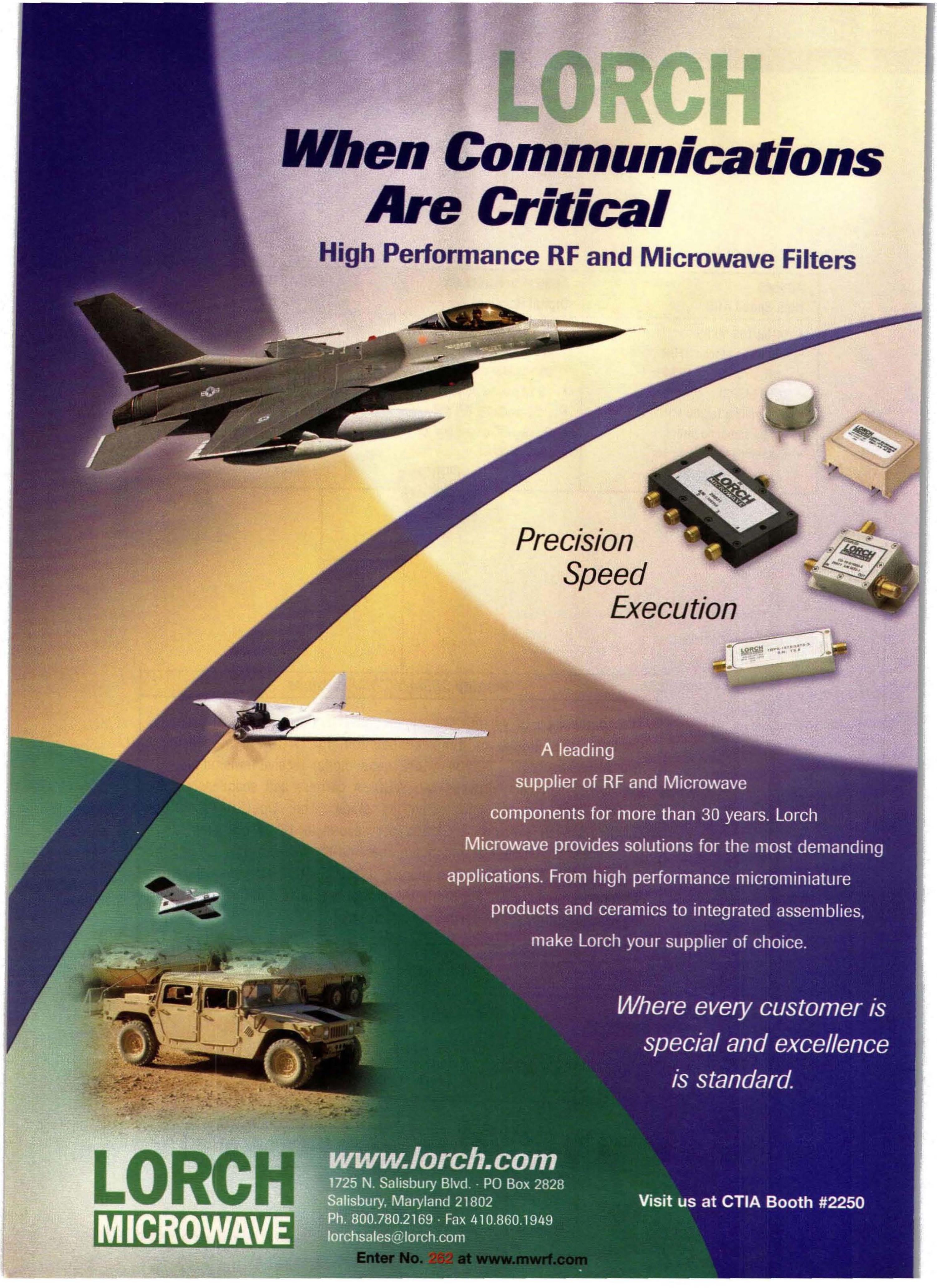
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Pricing Information

▶▶I ENJOY READING *Microwaves & RF* magazine and find that it has good articles as well as information about new technology and components.

One suggestion for improvement is to insist that the vendors put pricing information in products announcements and articles. This will help make your magazine become an increased productivity resource for engineers.

Jaffar Shah
Section Manager
R&D
National Instruments
Austin, TX

Editor's Note: Thank you for your kind words about the magazine. With the continued downturn in the economy, especially in many electronics markets, magazines such as Microwaves & RF *have been hard pressed to make their budgets for advertising revenues, which results in forced cost cutting. Some of the costs that are cut include editorial pages, which has resulted in a tremendous backlog of technical articles and other publishable materials (and our apologies to those authors who have been waiting to see their articles in print). The smaller magazines make for a greater challenge to provide an interesting mix of topics for our readers, since* Microwaves & RF *covers a wide range of technologies, from digital signal processing (DSP) to millimeter-wave devices.*

With regard to the pricing issue, this magazine does try to include pricing information whenever possible, often to the extent of making an extra call to a manufacturer for their prices. In the case of some products, such as software programs, having the price available can let a reader know the relative value of the program compared to other products with similar features. But in the case of some higher-priced items, such as test equipment and subsystems, pricing can be difficult because of the differences in pricing around the world (bear in mind that this magazine reaches over 45,000 readers in the US, Europe, South America, and the Far East). We will continue to try to provide the most up-to-date pricing information available to our readers.

PLEASE COMMENT

Microwaves & RF welcomes mail from its readers. Letters must include the writer's name and address. The magazine reserves the right to edit letters appearing in "Feedback." Address letters to:

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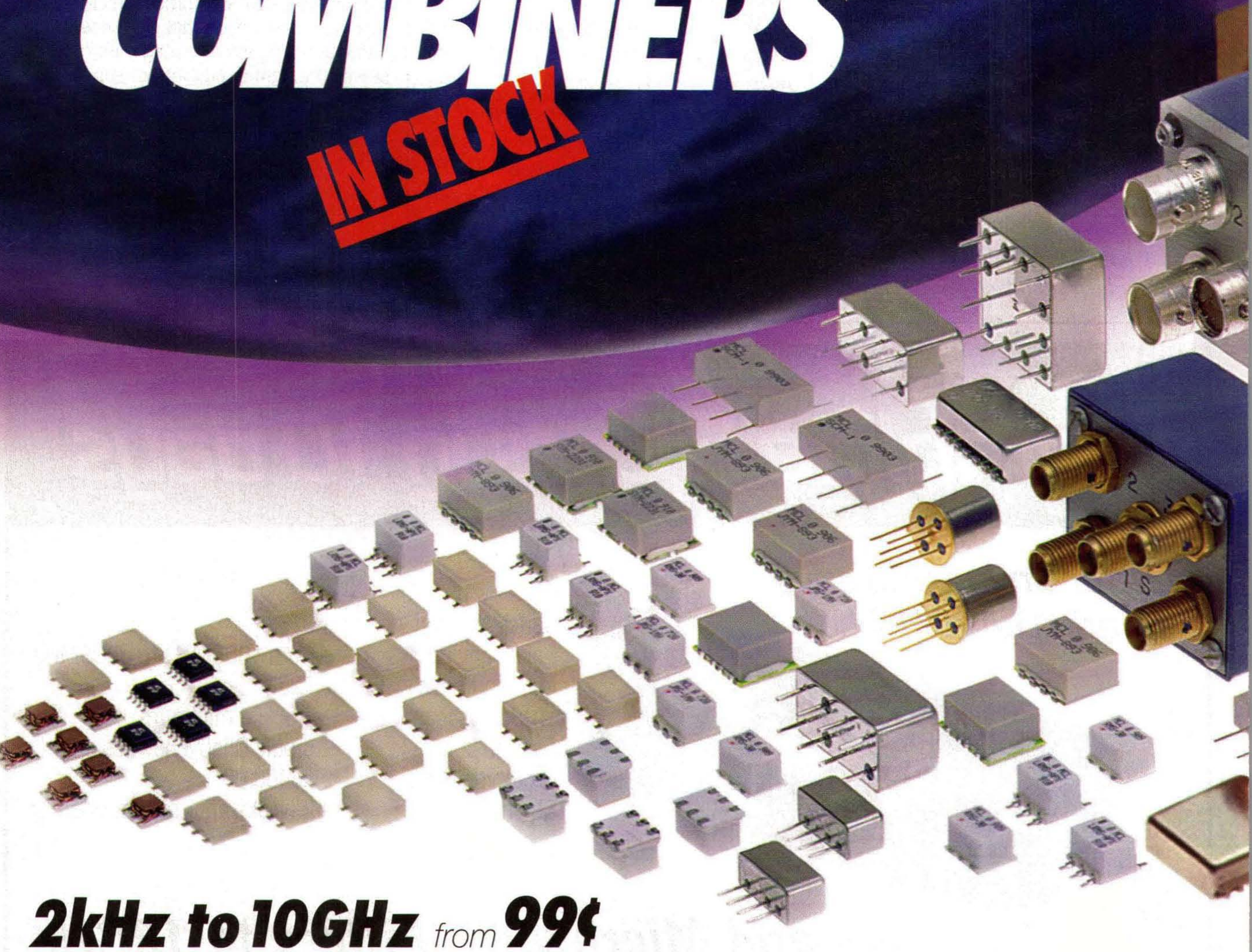

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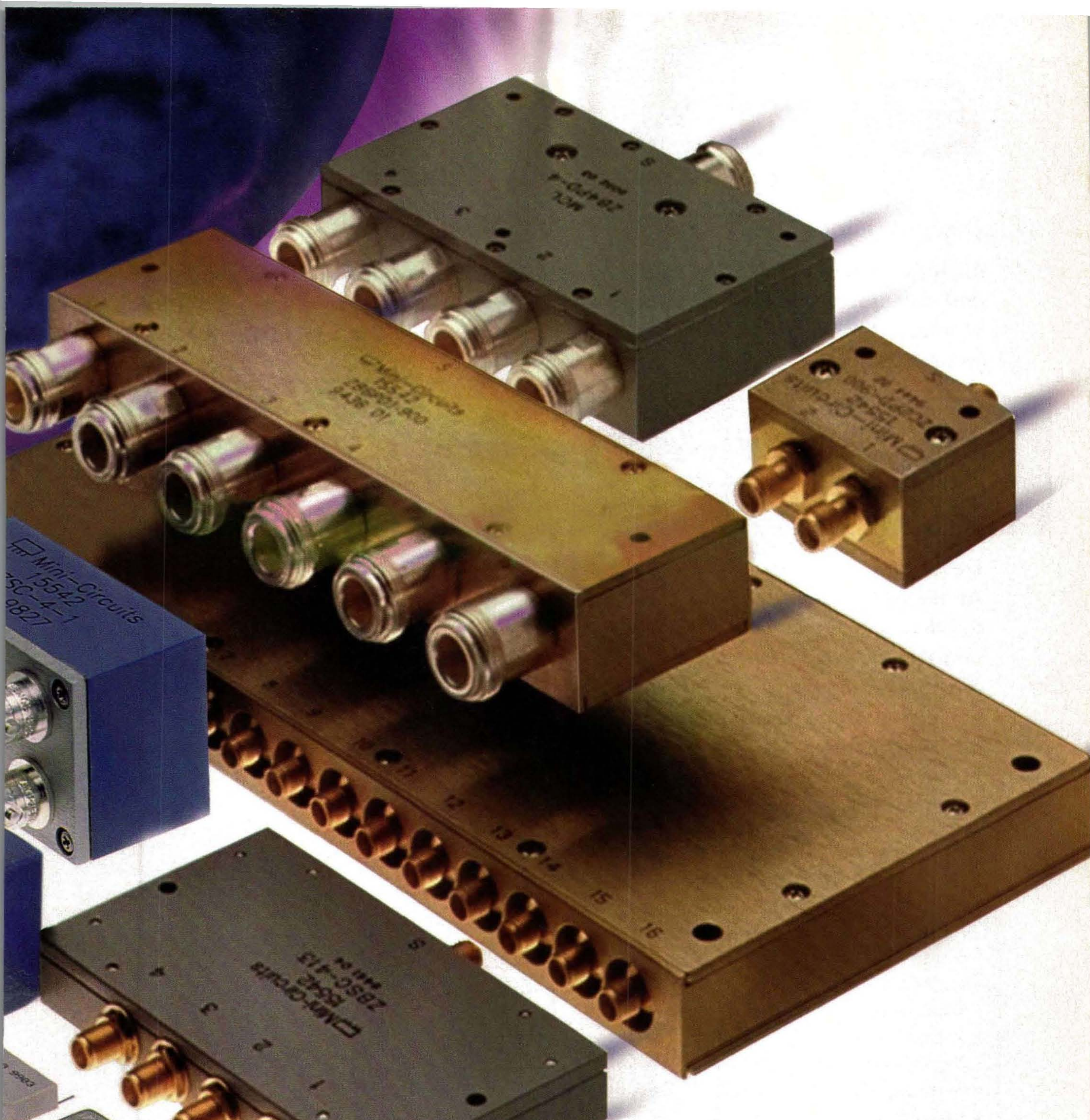

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Looking For The Next Best Thing

SURVEYING THE HIGH-FREQUENCY industry from an editor's chair has its occasional benefits, including a unique, noncompetitive view of products and technologies that few can match. Often it is one of the first looks at sometime outside of the employees at a particular manufacturer, giving an editor who is willing to travel amazing insights into the trends that characterize the industry, and the new developments that may one day change it.

One of the perquisites of the editor's position is a front-row view of emerging technologies.

Suffice it to say that with wisdom comes responsibility and often, in knowing about a new technology or product, the confidentiality offered to a magazine editor also requires that nothing be said about that knowledge until the proper time. Still, one of the perquisites of the editor's position is a front-row view of emerging technologies and, given a little thought and patience, the opportunity to connect the dots to see where new technologies might take us.

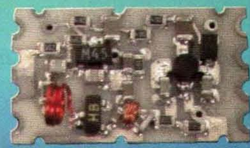
As scrutiny of the Top Products of 2002 might reveal (see p. 100), the communications marketplace is not dominated by any technology in particular and some older technologies, such as CMOS, are still doing quite well even when matched against the "next best thing" such as silicon germanium (SiGe). On that Top Products list, for example, are two Global Positioning System (GPS) receiver (Rx) integrated circuits (ICs)—a fact that in itself should indicate that the embedded GPS market may be poised for growth. These two GPS Rxs offer remarkably similar electrical performance in terms of power consumption (although differing somewhat in levels of integration), although one is fabricated with CMOS and the other with SiGe.

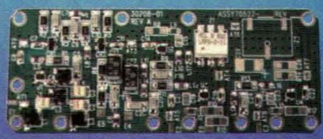
One of the technologies on the list—the ultrawideband (UWB) approach used by XtremeSpectrum in their data transceiver—certainly could be perceived as a threat to more traditional homodyne and heterodyne Rx architectures. But system developers so far have been somewhat wary of the UWB technology perhaps for fear that it may not coexist well with other more established technologies and applications, including GPS. And the Berlin-based Nanotron Technologies (www.nanotron.com) promises to make "noise" among RF design circles later this year with their multi-dimensional-multiple-access (MDMA) technology which, like UWB, promises high data rates with negligible power consumption. Like UWB, MDMA is based on a technology once solely in the domain of military electronics.

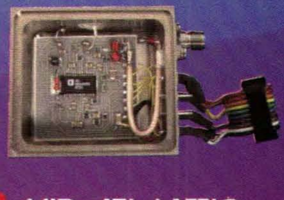
Will one of these technologies become the next best thing in wireless communications? That would be telling. But for sure, such innovative technologies are what keep engineering interested in constantly striving for that next best thing.

Jack Browne

Publisher/Editor







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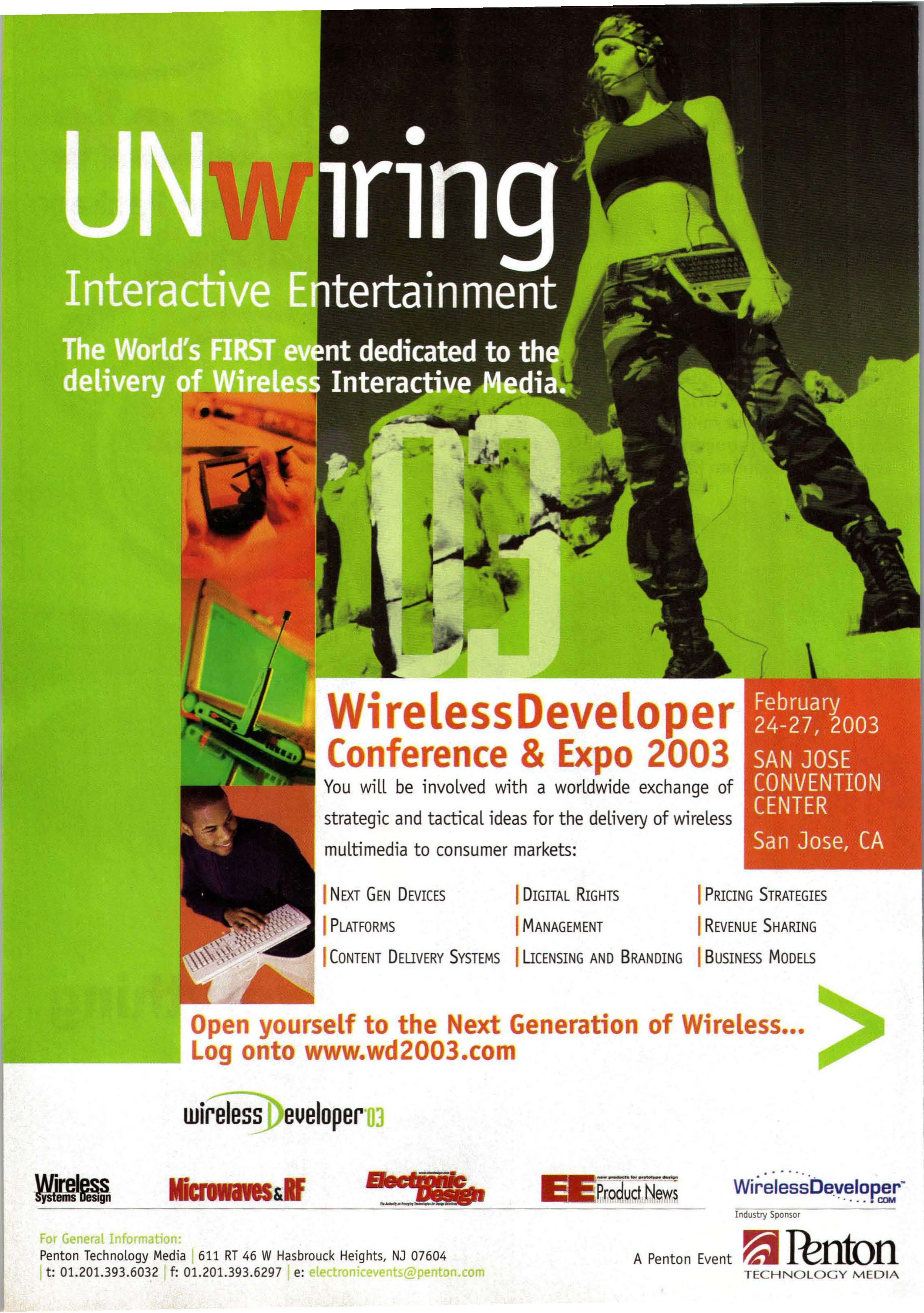

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the front end

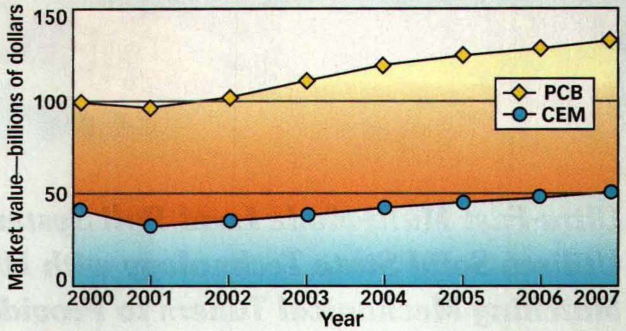
News items from the communications arena.

The PCB Industry Will Not Surpass Past Highs Before 2004

OYSTER BAY, NY—The printed-circuit-board (PCB) market reached a bottom in 2001, with worldwide sales expected to increase slightly in 2002 **(see figure)**. However, exceeding the levels posted in 2000, when global revenues topped $42 billion, will not happen for some time. Weaknesses in several tech sectors are to blame, including telecom, medical, and the broader information-technology (IT) industry, according to "Printed Circuit Boards: A Global Examination of the Printed Circuit Board, Contract Electronic Manufacturing, Semiconductor and Electrical Equipment Industries," a report from Allied Business Intelligence, Inc. (ABI).

"Given current market conditions, the PCB industry will take about four or five years to reach the level attained in 2000," commented Edward Rerisi, ABI's director of research. "The PCB market is strongly correlated with the electronic-equipment industry. As this industry recovers, so will the PCB market," Rerisi added. With nearly 2000 firms actively engaged in PCB production, ABI believes that only the most technically advanced companies will weather this storm. Smaller firms may be pushed out of the market unless they successfully cater to a niche application.

Printed-circuit boards (PCBs) and contract-manufacturing (CEM) market value
World market, moderate forecast: 2000 to 2007



(Source: Allied Business Intelligence, Inc.)

Further pressure mounts as Asian players continue to take advantage of their reduced labor and overhead expenses. Additionally, Asian PCB manufacturers benefit from their proximity to equipment production, typically outsourced in the region.

Development Agreement Is Reached For Chip Sets

SAN JOSE, CA AND PHOENIX, AZ—SiRF Technology, Inc. and Motorola's Semiconductor Products Sector (SPS) have announced an agreement to integrate SiRF's SiRFstarII Global Positioning System (GPS) core technology with Motorola wireless baseband and applications processors to location-enable a line of Motorola's SPS chip sets for mobile devices. This is SiRF's third announced agreement with Motorola.

Motorola plans to incorporate SiRF's advanced GPS technology into a line of location-aware wireless baseband and applications processor chip sets that will broaden the market for devices used for location-based services. The chip sets will utilize SiRF's SiRFstarII GPS baseband and RF IC core technology. Motorola intends to implement an enhanced version of SiRF's RF IC technology using the Silicon Germanium:Carbon module of its advanced RF BiCMOS wafer process. The planned GPS receiver (Rx) will incorporate Motorola IP enhancements for a higher level of integration with additional features for cellphone applications.

Mobile devices using these chip sets can take advantage of SiRFLoc™ multimode location technology to meet the market needs for location-based services, as well as to address accuracy and availability requirements contained in the US Federal Communications Commission (FCC) Enhanced 911 (E-911) mandate for wireless carriers. SiRFLoc multimode technology is being used by Nextel for E-911 emergency location and location-based services.

Worldwide Mobile-Phone Sales Exceed Expectations In The Third Quarter Of 2002

SAN JOSE, CA—In the third quarter of 2002, the mobile-phone industry exceeded expectations with a 7.8-percent increase from the same period last year, according to Dataquest, Inc., a unit of Gartner, Inc. Worldwide mobile-phone sales totaled 104.3 million units in the third quarter of 2002.

"This is only the second time ever that the third quarter has realized mobile terminal sales volume in excess of 100 million units," stated Bryan Prohm, senior analyst with the Mobile Communications Worldwide research group for Gartner Dataquest. "The most encouraging development was that each of the six principal geographic regions tracked by Gartner Dataquest recorded a sequential increase in demand.

"Each of the six principal geographic regions recorded a sequential increase in demand."

"The positive momentum generated during the first quarter of 2002 seems well positioned to carry over into the fourth quarter of 2002, when a wave of innovative mobile terminal models are expected to become widely available," continued Prohm.

Nokia further distanced itself from its competition in the third quarter, as its worldwide market share grew to 35.9 percent. Nokia was able to break through the 50-percent market-share barrier in the Western European market, as well as the larger Europe, Middle East, and Africa (EMEA) regional market.

Motorola saw its global market-share position decline during the third quarter, in large part because of critical delays in the availability of two new models—the T720 and C330—which were expected to ship in volume in the early part of the quarter.

Samsung had another strong quarter, as its market share surpassed 10 percent. At Samsung's current pace, it could achieve greater than 11 percent market share in the fourth quarter and be above the 10-percent mark for the full year.

In mature markets, such as Western Europe, mobile-phone manufacturers are facing more challenges in motivating users to purchase new phones.

"The highly penetrated nature of the Western European market means that future mobile terminals sales growth must now come from replacement purchases," said Ben Wood, senior analyst for Gartner Dataquest in Europe. "The combination of color, cameras, and content will drive this replacement cycle in the next eighteen months. Mobile terminal manufacturers will need to continually innovate to avoid a Western European market characterized by cyclical demand in coming years."

Firms Announce Availability Of Process Design Kit

EL SEGUNDO, CA AND TAIPEI, TAIWAN—Applied Wave Research, Inc. and WIN Semiconductors Corp. have announced the immediate availability of a process design kit (PDK) supporting WIN's power pseudomorphic high-electron-mobility-transistor (pHEMT) gallium-arsenide (GaAs) foundry process. The PDK provides monolithic-microwave-integrated-circuit (MMIC) engineers using AWR's Microwave Office™ 2002 design software, with an advanced circuit simulation and layout environment for designing with WIN's 0.15-μm process. Applications for these designs range from broadband communication, optical-fiber communications, automobile radar, and homeland-security systems.

"In today's fierce competitive market, time to market is very critical for our customers," stated D.P. Mathes, WIN Semiconductors' vice president of sales and marketing. "AWR's Alliance Program provides the venue for a sustained effort to dramatically accelerate time to market and reduce product-development costs for our customers. The new kit will greatly enhance product-design success from our existing customers and accelerate WIN's design capture rate."

The PDK offers automatic layout with design-rule check, pop-up help tips, and scalable models for pHEMT cells and passive components fabricated with the advanced wafer process at WIN. A menu-driven cell library is incorporated with transistor models covering a wide range of gate periphery. A complex scaling rule embedded in the model fosters high accuracy confirmed through power load/pull measurement up to millimeter-wave frequencies. The ease of use and maintenance saves the RF and MMIC engineers' time and money over previous methods of administering raw foundry standard cell models. WIN is extending this PDK development to other production processes that include the HBT, the 0.5-μm pHEMT, the 0.5-μm pHEMT Switch, the 0.5-μm E-mode pHEMT, and the 0.15-μm metamorphic high-electron-mobility transistor (MHEMT).

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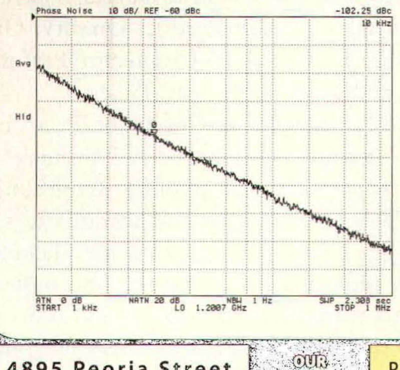
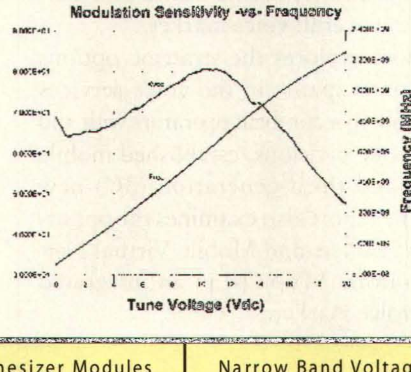
VCO790-2300T	2100-2500	1.0 - 4.0	-89 dBc/Hz	+5 V	+3 dBm	0.5 x 0.5 x 0.18 in.
VCO793-600T	400-800	0.0 - 20.0	-104 dBc/Hz	+12 V	+7 dBm	0.5 x 0.5 x 0.18 in.
VCO793-1500T	1000-2000	0.0 - 20.0	-99 dBc/Hz	+12 V	+7 dBm	0.5 x 0.5 x 0.18 in.

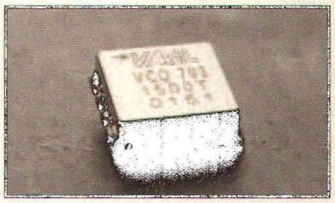
Actual data for VCO793-1500T

Phase noise from HP3852 for 1000-2000 MHz VCO



Tuning Sensitivity from HP3852 for 1000-2000 MHz VCO





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Price War In Western European Voice-Services Market Could Be Very Damaging

CAMBRIDGE, ENGLAND—A price war in the Western European voice-services market could cost fixed and mobile operators as much as EUR15 billion (approximately $15.4 billion US) in lost revenues over the next five years warns Analysys, a global adviser on telecoms and new media.

In its report, *The Future for Fixed-Mobile Substitution: options for fixed and mobile operators*, Analysys states that a price war could result in the value of the total voice market falling from EUR185 billion (approximately $189.3 billion US) in 2002 to EUR170 billion (about $174 billion US) in 2007.

> *"It is important for fixed and mobile operators to avoid a price war at all costs, as this would ultimately devalue the overall voice market."*

In this 'price war' scenario, fixed operators would see revenues decline by 14 percent from EUR96 billion (approximately $98.2 billion US) in 2002 to EUR83 billion (about $85 billion US) in 2007, with fixed call minutes remaining static at 1324 billion. Simultaneously, mobile operators' sales would fall by 2 percent from EUR89 billion (approximately $91 billion US) in 2002 to EUR87 billion (around $89 billion US) in 2007—despite a 69-percent increase in mobile call minutes from 310 billion to 522 billion.

"Fixed-mobile substitution is inevitable and will become more prevalent if the price difference between using a fixed and mobile phone is eroded significantly," stated Eddie Murphy, the author of the report. "However, it is important for fixed and mobile operators to avoid a price war at all costs, as this would ultimately devalue the overall voice market."

The report explores the strategic options for major participants in the voice-services market, including incumbent operators with and without mobile divisions, established mobile operators, and third-generation (3G) new entrants. The report also examines the opportunities for resellers and Mobile Virtual Network Operators (MVNOs) in an integrated European voice market.

Kudos

SAN DIEGO, CA—Ethertronics, a developer and manufacturer of internal antennas for personal and industrial wireless devices, announced that it has been honored as the Telecom category winner in the recent UC San Diego CONNECT Most Innovative New Product (MIP) Awards, a nationally recognized annual program showcasing the latest advancements in technology and life sciences. Ethertronics' DualNet™ MPCI internal antenna received the top award for its unique design and benefits to the wireless computing market.

WASHINGTON, DC—President Bush and Commerce Secretary Don Evans have announced the 2002 recipients of the Malcolm Baldridge National Quality Award, the nation's premier award for performance excellence and quality achievement. The Baldridge Award is managed by Commerce's National Institute of Standards and Technology (NIST) in conjunction with the private sector.

One of the recipients of the Baldridge Award is from the telecommunications industry. Motorola, Inc.'s Commercial, Government, and Industrial Solutions Segment, a Schaumburg, IL supplier of radio systems and products, received the Baldridge Award in the manufacturing category.

WESTLAKE VILLAGE, CA—Trompeter Electronics, a manufacturer of RF interconnect products for the telecommunications, military/aerospace, and broadcast-television industries, was ranked by customers as one of the industry's top performing connector manufacturers in Bishop & Associates' 2002 Connector Industry Survey. This is the fourth-consecutive year that Trompeter has moved up in rank in this annual research report.

Trompeter's performance among the 34 companies surveyed is attributable to their high scoring in those categories that respondents deemed most critical: Product Quality, On Time Shipping, Overall Connector Performance, and Reasonable Lead Times.

WESTBURY, NY—Sprague-Goodman Electronics, Inc. recently commemorated its 30th anniversary with a celebration ceremony in the company's Westbury, Long Island headquarters.

Sprague-Goodman's product lines include trimmer capacitors, fixed and variable inductors and transformers, tuning varactors, microwave-tuning elements, and insulated tuning tools.

REGENSBURG, GERMANY—Osram is now the leading company for patents relating to LED luminescence converters, with approximately 170 relevant patent applications worldwide in the key markets (Europe, Asia, and the US). MRF

NEWS

Wireless Show Spotlights Wireless Networking

Now in its 11th year, The Wireless Systems Design Conference & Expo highlights some of the more active areas of wireless communications, notably networks and Bluetooth.

Wireless design activity has never been at a higher level, at least according to engineers working on wireless-local-area-network (WLAN) and Bluetooth product solutions. While cellular design activity is now starting to accelerate, due to the gradual emergence and build-out of third-generation (3G) cellular systems, the explosive potential growth for wireless networks and Bluetooth is the result of over-hyped, slow-to-develop markets that are only now coming to fruition. The technical advances behind these markets will be explained at the upcoming technical sessions of the Wireless Systems Design Conference & Expo, scheduled for February 24-27, 2003 in the San Jose Convention Center (San Jose, CA). Visitors will also have the opportunity to see and touch hardware, software, and test equipment while visiting the hundreds of exhibitors on the Wireless Systems Design Conference & Expo show floor.

JACK BROWNE
Publisher/Editor

The technical sessions for The Wireless Systems Design Conference & Expo begin on Monday, February 24th, with five full-day workshops. Manufacturers' exhibits open the following day. The five workshops include "Oscillators for Wireless Applications" by Randy Rhea of Eagleware; "Bluetooth Radio Design" by Ken Noblitt of Cambridge Silicon Radio; "Antennas & Propagation for Wireless Communications" by consultant Steve Best; "Packaging for Wireless RF" by Sam Horowitz of Dupont; and, new to the 2003 conference, "Power Management for Mobile-Communications Devices" by Bill Krenik who is Wireless Advanced Architectures Manager for the Wireless Terminals Business Unit of Texas Instruments. This latest addition to the conference will examine different approaches for minimizing power consumption in wireless handsets, notably as customers demand more functions, such as display screens and gaming, from their handheld devices.

Technical sessions will commence on Tuesday, February 25th, and conclude on Thursday, February 27th. These will consist of largely one-half-hour sessions, grouped into track categories that include Bluetooth & Short-Range Communications, Broadband/Fixed Wireless, Handset Design, Power Management, Reference Designs, RF ICs for Wireless Design, Software, Wireless Internet, Wireless LAN, Wireless Modeling/Test & Measurement, and Wireless Networking. Technical presentations are organized by Conference Co-Chairpersons Cheryl Ajluni, Editor-In-Chief of *Wireless Systems Design* magazine, and Jack Browne, Publisher/Editor of *Microwaves & RF* magazine.

While many of the technical tracks may appear familiar to repeat attendees of the conference, the Reference Design track is new. Reference designs are circuits developed by integrated-circuit (IC) manufacturers, usually developed in conjunction with a customer. They provide a "starting point" for other designs, and a useful way for engineers to see how a chip or chip set is used in an example application. In some cases, the reference design may actually be the heart of an application, minus some critical intellectual property, such as software. Each reference design presentation will offer attendees a chance to scrutinize a schematic diagram and design layout, and hear about troubleshooting and measurement techniques from one of the reference-design's creators. Presentations confirmed so far for the Reference Design track include designs for WLANs, cellular telephones, and embedded Global Positioning System (GPS) circuitry. For example, Aditya Agarwal of Fujitsu Microelectronics America (Santa Clara, CA) will explore a reference design focused on wireless broadband metropolitan area networks, notably a design in support of interoperable systems such as IEEE 802.16a and ETSI-BRAN HIPERMAN. The report will look in detail at the OFDM physical layer (PHY) solution that is common to both IEEE 802.16a and HIPERMAN, with details about a possible system-on-chip (SoC) implementation and the type of reference design needed to evaluate this solution. Bernard Olivier of California Eastern Laboratories (Santa Clara, CA) will address reference designs for embedded GPS applications, in partnership with customer eRide.

A sampling of other technical presentations include several discussions on WLANs, including Carl Andren of Intersil Corp. who will present a report on zero-IF architectures for dual-band WLAN radios and Richard Abrams of Intersil who will offer a troubleshooting guide for designers of dual-band WLAN radios. Steve Saltzman of Intel Corp.'s Wireless LAN Operation will discuss enterprise applications for WANs and WLANs, while Monica Bhatnager and Edward Brown of Agilent Technologies will detail an enhancement-mode PHEMT amplifier for WLANs.

In the session on Wireless Internet, Diane Ort of Edgewater Technology will explore how organizations can leverage web services to communicate with wireless devices while providing consistent data, improved customer satisfaction, and expanded services and market reach. Gerald Bolden of Micron Technology's Network and Communications Group will address memory organization for optimization of high-speed packet processing systems. And Shridhar Krishnamurthy, a co-founder of Cyneta Networks, will cover the requirements for successful mobile-data systems. In addition, Stephen Hester of Aloha Networks will explain his company's patented Spread ALOHA Multiple Access (SAMA) technology for improving the return-channel efficiency of wireless networks.

In the session on Wireless Networking, Tim Cutler of Cirronet, Inc. will explore the challenge of connecting non-TCP/IP devices to TCP/IP networks, and look at how current and future wireless technologies, including ultrawideband (UWB) technology, might offer a solution for this problem. Ember Corp.'s Vice-President of Engineering, Andy Wheeler, will detail differences between mesh, point-to-point, and point-to-multipoint networks, how to overcome RF interference and line-of-sight problems, and benefits offered by wireless mesh networks compared to other wireless network solutions. Bruce Gray of Ethertronics will illustrate how advances in antenna technology can capture more available signal than conventional approaches.

Tuesday, February 25th, will also feature a Keynote address from Gadi Singer, Vice President of the Wireless Communications and Computing Group, and General Manager of the PCA Components Group of Intel Corp. From 1993 to August 1998, Mr. Singer served as the general manager of the Microprocessor Products Group's Design Technology Division. He became co-General Manager of the IA-64 Processor Division in 1998 and General Manager of the Enterprise Processors Division in 2000. He was appointed Vice-President in January 1999, and most recently managed the entire product development of the company's Itanium processor. Mr. Singer will provide insights into future market prospects for wireless technology in commercial, consumer, and enterprise areas, as well as a rare inside look at Intel's plans for wireless and portable markets.

The WirelessDeveloper Conference & Expo 2003 will be co-located for the first time with The Wireless Systems Design Conference & Expo in the San Jose Convention Center. The event will address all facets of wireless entertainment, from fundamental building blocks to final end-user delivery approaches. It will offer studios, media, and entertainment professionals an opportunity to interact directly with operators, manufacturers, and technology providers for next-generation wireless devices and platforms. The event includes wireless gaming, next-generation device technologies, system design, digital rights management, branding, licensing, business models, media delivery, and merchandising strategies. For more information on The Wireless Systems Design Conference & Expo, visit the website at www.wsdexpo.com for updates on technical presentations and exhibitor news, as well as information on attending the conference. MRF

ARMMS Meeting Tackles Measurement Issues

The most recent meeting of the ARMMS RF and Microwave Society Meeting focused on power-measurement strategies for wireless and optical communications systems.

JACK BROWNE
Publisher/Editor

Power measurements require care and precision. Some of the leading engineers involved with power measurements discussed their strategies at the most recent ARMMS RF and Microwave Society Meeting, held October 28-29, 2002 in the Tortworth Hotel (Tortworth, South Gloucestershire, England). ARMMS is a UK-based organization dedicated to the design and measurement of devices and products oper-ating at RF and microwave frequencies. Sponsored by the National Physical Laboratory (NPL, Teddington, Middlesex, England), the two-day conference was aptly organized by NPL's David Adamson.

At ARMMS, K.P. Holland, J. Howes, and C. Purser of the NPL's Centre for Electromagnetic and Time Metrology described some of their techniques for improving attenuation measurements by minimizing signal leakage. In their attenuation measurement system, any signals reaching the detector other than the desired signals are considered leakage. A leakage signal 80 dB lower than the signal path can result in an error of 0.001 dB in an attenuation measurement. The system passes test signals through a gauge block attenuator and the device under test (DUT) before being downconverted to a lower frequency of either 10 or 50 kHz. These lower signals are then measured with a calibrated commercial AC digital voltmeter.

After exploring different approaches for detecting leakage, the presenters found that the most effective device for detecting leakage is a phase-sensitive detector (PSD), often referred to as a lock-in amplifier. They can be used as vector voltmeters to measure the amplitude and phase of signals having a coherent phase relative to a reference signal. The approach can reliably measure signals at levels of –150 to –170 dBm, but it requires a reference input. In this case, a 5-kHz reference was used—one-half the frequency of the 10-kHz intermediate frequency (IF). For measurements through microwave frequencies, the system has been able to detect levels as low as –170 dBm and, with a RF or microwave signal source of +20 dBm, the approach has shown a measurement range as wide as 190 dB for signals from 10 to 100 MHz.

Winner of the "Best Paper" award went to Nick Long of Great Circle Design (Somerset, England) for his exploration of using a vector network analyzer for oscillator design. His very practical presentation detailed some of the problems that could be "debugged" with his approach, including oscillators that will run but won't start, overtone crystal oscillators running on the

wrong overtone (or fundamental frequency), oscillators that oscillate on more than one overtone simultaneously, spurious oscillations at frequencies well beyond the design frequency, and voltage-controlled oscillators (VCOs) that change behavior as they are tuned. His approach is based on performing S_{11} measurements on oscillator circuits and making use of Smith Chart plots to interpret the behavior of malfunctioning sources.

In other presentations, Alan Coster of Dowding & Mills Calibration compared different techniques for measuring RF voltage, along with techniques for calibrating an RF voltmeter. Guy Purchon of Anritsu Ltd. (Stevenage, Hertsfordshire, England) detailed accurate power measurements on modern communications systems, concentrating on root-mean-square (RMS) power measurements on code-division-multiple-access (CDMA) and quadrature-amplitude-modulation (QAM) signals.

A.D. Vare and R. Hopper from Roke Manor Research (Romsey, Hantsfordshire, England) explained how the 3GPP specifications for base stations impact the choice of power-amplifier (PA) and its devices, and how measurements can assist in making the choice.

Graham Pearson and Liam Devlin of Plextek Ltd. (Great Chesterford, Essex, England) described a dual-channel 2-to-18-GHz receiver front-end module for Electronic Support Measures (ESM) applications. The module converts signals, received by two external antennas, from anywhere in the 2-to-18-GHz range to an IF suitable for digitization. Frequency conversion is realized by upconverting to an intermediate frequency (IF) at around 22 GHz before filtering and then downconverting to the IF. The module contains 12 GaAs MMICs, a total of five designs, four of which are custom ICs designed by Plextek.

Chris Potter of P&H Technology Consultants (Cambridge, England) examined the predistortion linearization of a multicarrier WCDMA PA, using a predistorter application-specific integrated circuit (ASIC) from Intersil. He examined different biasing schemes (Class AB and Class C) for the best combination of linearity and efficiency.

The next ARMMS meeting is scheduled for April 7-8 at the Hotel Elizabeth (Corby, Northamptonshire, England). The Program Coordinator is Dominic FitzPatrick of Milmega (Ryde, Isle of Wight, England). Those interested in presenting a paper or attending can contact Dominic at: **Milmega Ltd., Nicholson Rd., Ryde, Isle of Wight PO33 1BQ, England; (44) 1983-618007, FAX: (44) 1983-616864, e-mail: dominic@milmega.co.uk.** MRF

LNA Module Spans 12.7 To 26.5 GHz

MODEL NB00407 IS A miniature low-noise amplifier (LNA) module designed for applications from 12.7 to 26.5 GHz. Fabricated with a thin-film microwave-integrated-circuit (MIC) process, the LNA module is designed for use with a single voltage supply. It achieves typical noise figure of 4.5 dB while also providing 22 dB typical gain and +20 dBm output power at 1-dB compression. The LNA module, which is specified for operating temperatures from –30 to +70°C, is aimed at satellite and other telecommunications systems.

Nextec Microwave & RF, Inc., 2255-E Martin Ave., Santa Clara, CA 95050; (408) 727-1189, FAX: (408) 727-5915, e-mail: sales@nextec-rf.com, Internet: www.nextec-rf.com,

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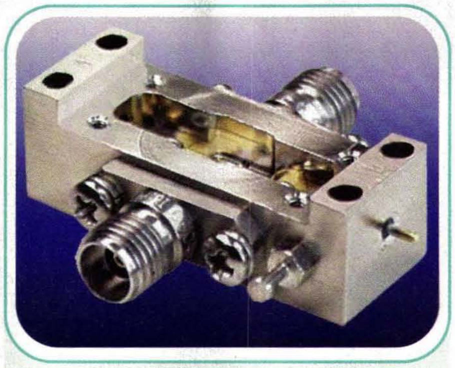
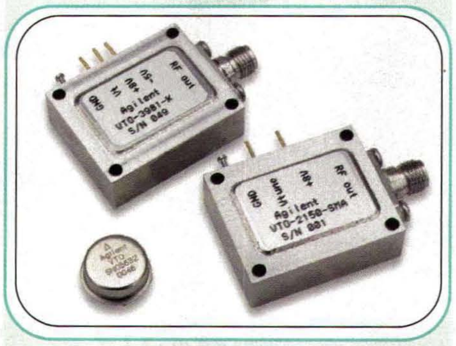


NEXTEC MICROWAVE & RF'S MODEL NB00407



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Agilent Technologies, Inc., 3175 Bowers Ave., Santa Clara, CA 95054; (800) 235-0312, FAX: (408) 654-8575, Internet: www.agilent.com/view/rf.

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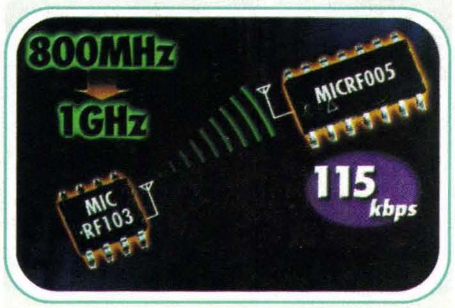
LPKF LASER & ELECTRONICS' PROTOMAT H100



MICREL SEMICONDUCTORS' MICRF005 RX AND MICRF103 TX

System Speeds PCB Prototyping

THE PROTOMAT H100 plotter system allows significant reduction in the time needed to prototype printed-circuit boards (PCBs). The system offers a maximum milling speed to 4 in./s. An integrated smart following-vector path generation allows the system to maintain a higher average speed than previous systems of this type. The system supports prototype production of six- and eight-layer PCBs, with resolution to 1 µm. The system employs a 100,000 rpm milling motor which allows the plotter to create 3-mil tracks with 4-mil spacing to accommodate the latest package types, including BGA and micro-BGA packages.

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Micrel Semiconductor, 1849 Fortune Dr., San Jose, CA 95131; (408) 944-0800, FAX: (408) 944-0970, Internet: www.micrel.com.

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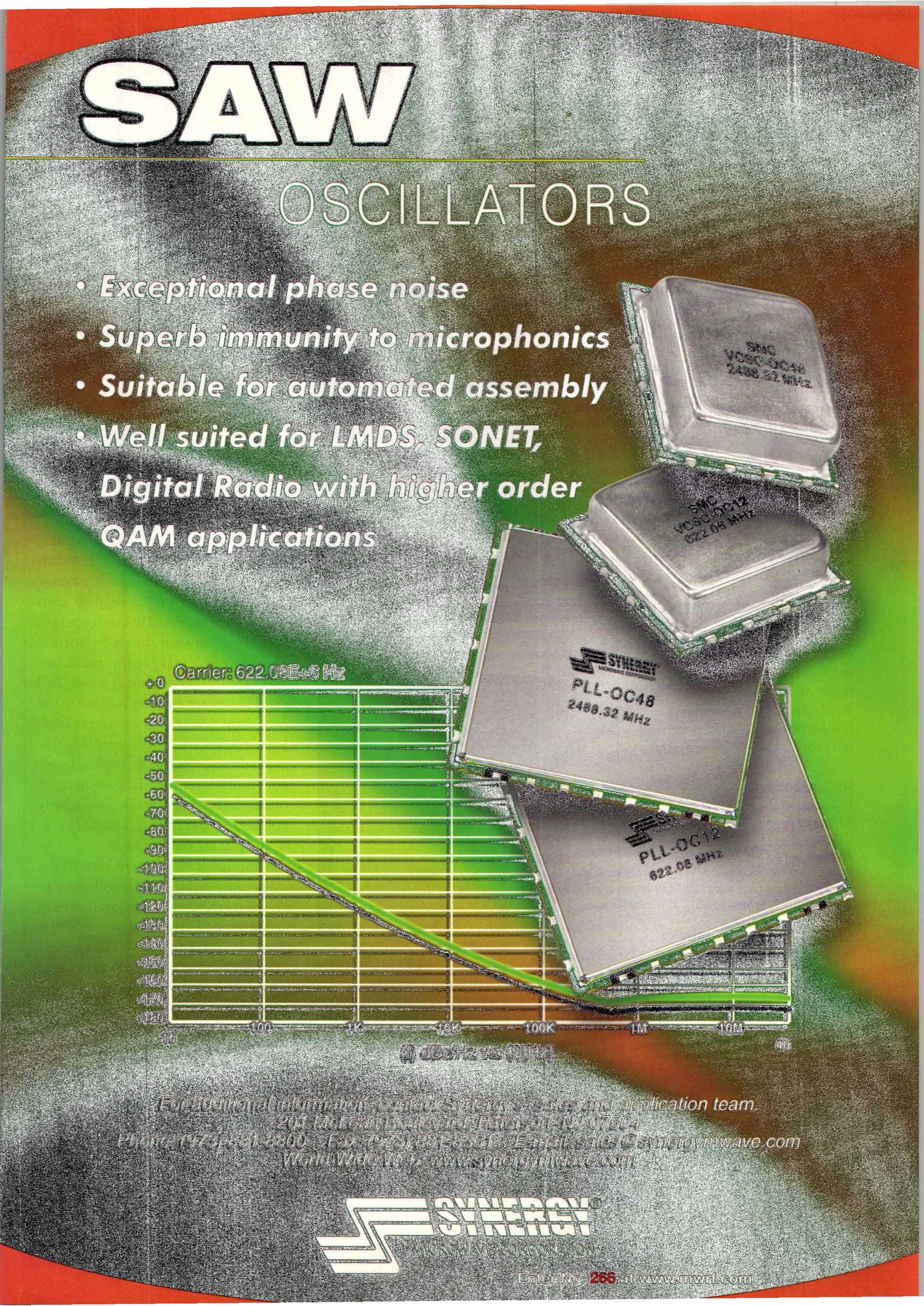

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China Will Dominate PCB Growth

THE PRINTED-CIRCUIT-BOARD (PCB) MARKET did not perform well during 2002, according to *Printed Circuit Boards 2002—China Will Dominate PCB Growth*, a report from iSuppli Corp. The figures from around the world do not provide reasons for optimism. The US PCB market performed very poorly in 2002. Revenues were down 15 percent in 2002. This comes on the heels of a 30-percent decrease in revenues in 2001. Europe also did not perform well, but not as poorly as the US.

The story is quite different for Asian PCB producing nations, however. Taiwan performed well; Japan has pulled out positive year-on-year growth; and China dominated worldwide PCB revenue growth with approximately 15-percent year-on-year growth. China is clearly the bright spot in PCB growth for the next five years.

Unfortunately, there was considerable PCB price erosion in 2002, specifically in Asia, where these trends are most notable. Although price slippage continues and is expected to continue into 2003, it is slowing down to normal year-on-year levels. Many manufacturers are still producing at a loss, and board prices are extremely close to the cost of raw materials in some cases. However, because there is still significant capacity, specifically for low layer-count multi-layer boards, there remains considerable competition, particularly on 4- and 6-layer boards, which is keeping the pricing trend down.

Although upticks were seen in the second quarter on fiberglass cloth pricing and copper and chemicals had been on a sustained rise since late in 2001, all of these trends have stopped or reversed. No further increases in fiberglass cloth have taken place, and there is ample glass fiber capacity worldwide to satisfy the projected upturns in demand. In addition, copper prices were on the slide during the beginning of the third quarter.

PCB capacity utilization remains very low worldwide, averaging 50 to 60 percent, with at least one region, the US, reporting utilization as low as 30 to 35 percent. Inventories in the supply chain are at the lowest levels since the beginning of 1999. MRF

CONTRACTS

Yokogawa Corp. of America—Has been awarded an exclusive contract by IDEC Pharmaceuticals Corp. to provide all pressure, differential pressure, temperature, and conductivity transmitters (Txs) to the pharmaceutical manufacturer.

The New IDEC Manufacturing Operation (NIMO), Phase 1, will provide capacity to manufacture products used primarily in the treatment of cancer, autoimmune, and inflammatory diseases. The manufacturing facility will be applying Yokogawa digital instrumentation using FOUNDATION Fieldbus™ as well as device-net communication protocols provided by other vendors.

Motorola—Announced that it has been awarded a multimillion-dollar contract by Toshiba to provide a digital-communications system for the Taiwan High Speed Rail Corp. This system marks the world's first TETRA (TErrestrial Trunked RAdio) contract for the high-speed rail industry and the first TETRA contract in the Republic of Taiwan for Motorola.

Motorola's suite of TETRA-compliant offerings is called Dimetra™. Motorola will provide a Dimetra system that will bring digital communications to Taiwan High Speed Rail's entire 345-km track, including tunnels, train stations and depots, as well as high-speed trains plying at 300 km/h.

Herley Industries, Inc.—Announced that Herley Israel has received a $1.25 million contract award from Indra Sistemas, S.A. for microwave components to be integrated into electronic-warfare (EW) systems. Indra is involved in Spain's defense industry and is active in many of Europe's primary defense programs.

Herley and Indra are partners in MRCM, an alliance founded in 2000 to provide complete solutions and products for SIGINT and tactical EW systems to customers worldwide. The other partners are EADS ewation (EADS owns 80 percent of Airbus), Grintek ewation, and Sysdel.

FRESH STARTS

Linx Technologies—Announced that construction has begun on their new corporate headquarters. The 20,000-sq.-ft. building is designed to maximize efficiency and employee comfort, as well as better accommodating continued growth. The new facility includes recreational features such as a lake complete with paddle boats, a putting green, an arcade/game room, and a 1950s theme dining room. The new facility is located in Merlin, OR, a small town that adjoins the present Linx site in Grants Pass. Construction of the facility is expected to be complete this summer.

Intertek Testing Services plc, ETL SEMKO Division—Has been recognized as a Bluetooth Qualification Test Facility (BQTF) to provide RF conformity testing of products using Bluetooth technology. As of January 1, 2003, only recognized BQTFs can provide can provide this testing, mandated by the Bluetooth Special Interest Group (SIG). ETL SEMKO is currently one of only 14 BQTFs worldwide.

ParthusCeva, Inc., Parthus Technologies plc, and DSP Group, Inc.—Jointly announced that the combination of Parthus and Ceva, Inc. has closed.

The common stock of the combined company, now called ParthusCeva, has begun trading on NASDAQ under the symbol "PCVA" and on the London Stock Exchange under the symbol "PCV."

Ansoft Corp.—Announced financial results for its second fiscal quarter that ended on October 31, 2002.

Revenue for the second quarter of fiscal 2003 totaled $10.6 million, an increase of 14 percent as compared sequentially to $9.3 million reported in the previous quarter and a decrease of 16 percent as compared to $12.5 million reported in the previous fiscal year's second quarter. Net loss for the second quarter of fiscal 2003 was $2.2 million , or $0.19 per diluted share, compared to a net loss of $65,000, or $0.01 per diluted share, reported for the same quarter in the prior fiscal year.

Etenna Corp.—Has secured a $3 million Series D round from ECentury Capital Partners of McLean, VA and New York-based Archery Capital. This brings the company's total funding to $21 million, with earlier capital rounds sponsored principally by The Titan Corp. and Archery Capital.

Credence Systems Corp.—Announced that Ralink Technology Corp. has selected Credence's ASL 3000RF™ test system. Ralink selected the system based on its ability to meet the significant technical and economic challenges presented by next-generation wireless devices and applications, including 802.11b standards.

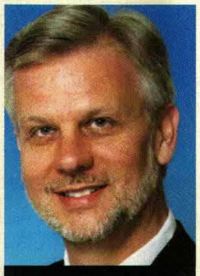
The ASL 3000RF features advanced RF instrumentation with both digital and baseband analog tools. Additionally, the system incorporates Credence's patented modulated vector network analysis (MVNA™) technology, the first major technology breakthrough in S-parameter measurements in 30 years.

Eagleware Corp.—Announced the successful implementation and verification of Motorola's Electro Thermal laterally diffused metal-oxide-semiconductor (MET LDMOS) model design kit, for use with Eagleware's nonlinear circuit simulator,GENESYS 2002.09.

The library, which incorporates the transistor models for Motorola LDMOS devices, accounts for the nonlinear and temperature characteristics of the devices commonly found in high-power microwave and RF applications, such as mobile base stations. The complete design kit contains the MET transistor models, electrical-package models, and models for bond wires and intrinsic matching for Motorola's current LDMOS products. Motorola specifically tailored the model to simulate high-power RF LDMOS transistors used in wireless base-station applications. Due to its ability to simulate self-heating effects, the MET model is more accurate than existing models. MRF

people

ITT Industries, Avionics Appoints Bernhardt


BERNHARDT

ITT Avionics Division has named CHRISTOPHER C. BERNHARDT as its president and general manager. Bernhardt was previously the vice president and director of programs at ITT Industries, serving in that capacity since 2001.

Boonton Electronics—HUGH FELGER to Eastern regional sales manager; formerly sales manager at Advantest America Measuring Solutions, Inc.

RF Micro Devices, Inc.—BOB BRUGGEWORTH to CEO; remains as president. DAVID NORBURY continues as a member of the board of directors; retiring as CEO.

JMAR Technologies Inc.—RONALD A. WALROD to president and CEO; formerly president and CEO of Kinetic Probe.

Oracle Corp.—H. RAYMOND BINGHAM to the board of directors; remains as president and CEO.

SiRiFIC Wireless Corp.—MICHAEL HOGAN to president and CEO; formerly general manager at Texas Instruments.

Current Analysis—ROBERT BLAIR to vice president of finance; formerly vice president of finance with ScoreBoard, Inc. Also, DAVID PITZER to vice president of technology; formerly vice president of Internet technology at Lightspan, Inc.

RedVector.com—WADE N. HOY to the position of director of corporate training; formerly worked in sales at Delco Remy America.

Tyco International Ltd.—DAVID E. ROBINSON to president of the Plastics and Adhesives Group; formerly president of Motorola's Broadband Communications Sector.

Enthone, Inc.—DAVE PENMAN to vice president of operations; formerly involved in microelectronics at Arch Chemicals and Olin Corp. Also, DR. CHONGLUN FAN to senior scientist; formerly R&D principal investigator and a member of the technical staff with the former Electroplating Chemicals & Services division of Lucent Technologies. In addition, DR. CHEN XU to senior scientist; formerly project leader and a member of the technical staff with the former Electroplating Chemicals & Services division of Lucent Technologies.

Anadigm—WILLIAM MCLEAN to CEO and president; formerly president of US operations at ParthusCeva.

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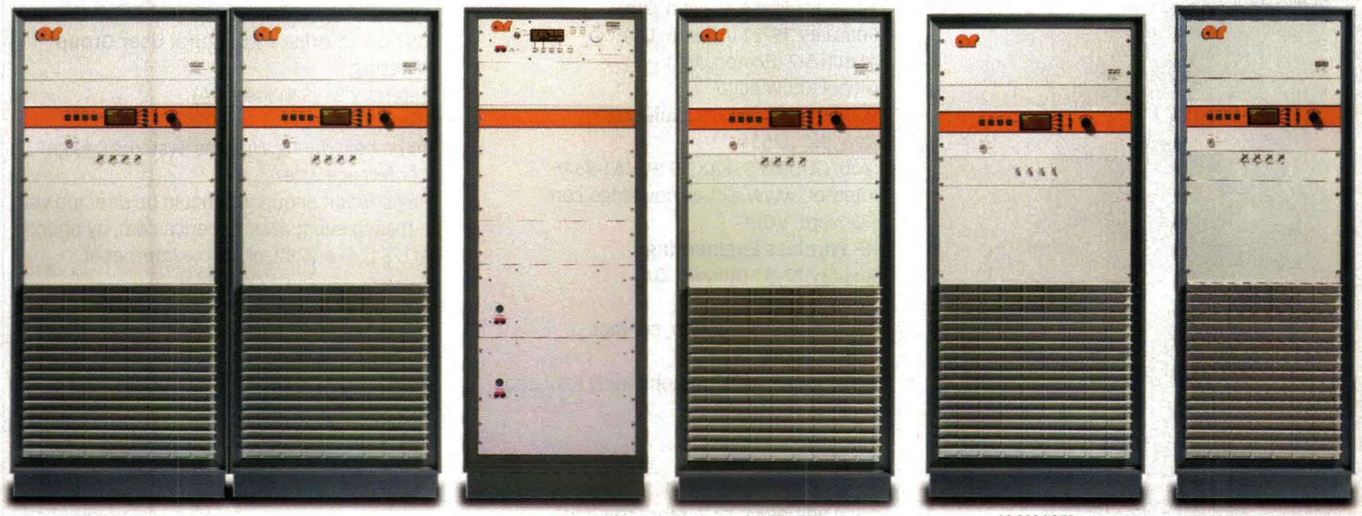

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True Logarithmic Amplifier Provides Coverage From DC To 4 GHz

LOGARITHMIC AMPLIFIERS (logamps) are commonly used in radar systems to process the wide dynamic range of received signals. Scattering and multipath effects can result in a requirement for 100 dB dynamic range to properly process signals from a radar system. Fortunately, Chris D. Holdenried and associates from the Department of Electrical and Computer Engineering of the University of Calgary (Calgary, Alberta, Canada) have developed a 40-dB dynamic-range, parallel-summation logamp capable of operating from DC to 4 GHz. It realizes a piecewise approximation of an exact log response. Based on a 35-GHz silicon bipolar semiconductor process, the amplifier exhibits maximum group-delay variation of only 35 ps with rise and fall times of 100 ps or better. With ±5-dB logarithmic conformity, the device is suitable for both military applications as well as for baseband processing in high-speed fiber-optic communications systems. See "A DC-4-GHz True Logarithmic Amplifier: Theory and Implementation," *IEEE Journal of Solid-State Circuits,* October 2002, Vol. 37, No. 11, p. 1290.

Multimode Horn Handles Millimeter- and Submillimeter-Wave Frequencies

AN IMPROVED DUAL-MODE HORN has been developed for Gaussian mode generation at millimeter-wave and submillimeter-wave frequencies. Based on the research of Jeffrey M. Neilson of Calabazas Creek Research (Saratoga, CA), the device is easier to construct than corrugated designs. The author built a version of the horn for testing at 110 GHz with excellent agreement to his models. See "An Improved Multimode Horn for Gaussian Mode Generation at Millimeter and Submillimeter Wavelengths," *IEEE Transactions on Antennas and Propagation Communications Magazine,* August 2002, Vol. 50, No. 8, p. 1077.

Analyze The Effects Of Adjacent Channels On RF Amplifier IP3

AMPLIFIER LINEARITY is a key requirement for existing and emerging wireless communications systems, including third-generation (3G) cellular systems. For practical RF amplifiers, the relationship between the input and output is not linear, and is usually characterized by such parameters as the 1-dB compression point and the third-order intercept point (IP3). But because channels in wireless systems are so closely spaced, signals from adjacent channels are often processed by an amplifier along with the desired carrier. And, as investigations by Jian-Guo Ma of the School of Electrical Engineering of Nanyang Technical University have uncovered, the effects of adjacent-channel power can be significant on the measured 1-dB compression and IP3 performance of RF amplifiers. Due to the nonlinear effects of amplification, signals in adjacent channels can be transformed to the frequency of the desired channel. These signals cannot be filtered out and thus are amplified along with the desired carrier. The author redefines the mathematical relationships for IP3 and presents a simple equation to analyze the effects of this nonlinear transformation on the adjacent channels and the ultimate effects on the 1-dB compression and IP3 performance of an RF amplifier. The author suggests that the quality of the desired channel signal can be estimated by means of the ratio of the intermodulation signal strength to the total output signal strength at the desired frequency in percentages. See "Effects of the Adjacent Channels on IP3 of RF Amplifiers," *Microwave and Optical Technology Letters,* October 5, 2002, Vol. 35, No. 1, p. 1.

Experiments Study Temporal Variations In 1.8-GHz Indoor Radio Channels

INDOOR RADIO CHANNELS, due to the relative movement of users and machinery, must withstand the effects of multipath fading, known as temporal fading or temporal variations. Both temporal and spatial variations are usually present in indoor mobile or wireless communications environments. Susana Loredo of the Department of Electrical Engineering of the University of Oviedo (Asturias, Spain) and Rafael P. Torres of the Department of Communications Engineering of the University of Cantabria embarked on a series of measurements at three locations at the University of Cantabria to study the effects of temporal variations. The effects of the motion of people, for example, were found to be small (only about 2 Hz for low-amplitude signals), while the average duration of fades in the three environments was found to be very short. The researchers also found similarities between results at 1.8 and 2.4 GHz. See "Experimental Analysis of Temporal Variations in Indoor Radio Channels at 1.8 GHz," *Microwave and Optical Technology Letters,* October 20, 2002, Vol. 35, No. 2, p. 132.

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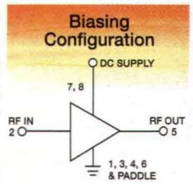

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MNA-6	0.5-2.5	5.0 2.8	23.6 21.2	18.0 14.1	2.25
MNA-7	1.5-5.9	5.0 2.8	15.9 13.7	15.6 12.7	2.25
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DESIGN

Performing Bluetooth RF Radio Testing

Measurement and analysis of Bluetooth RF radios require a mix of instruments and approaches some of which are not called out in the standards documentation.

Bluetooth radio designs employ a number of system architectures, from conventional intermediate-frequency (IF)-based systems with analog modulation to digital in-phase/quadrature (I/Q) modulator/demodulator configurations. Currently, various forms of modules are being used. Ultimately, circuit-level integration may be required for the lowest BOM. Regardless of how the Bluetooth design is configured, numerous issues must be addressed, including global regulatory requirements, Bluetooth certification, development of simple, high-yield manufacturing and test procedures, and flawless interoperability with designs from other vendors, some of which may perform at the limits of the Bluetooth specification. This article will examine different features of Bluetooth designs, implications for research-and-development (R&D) tests, and the tools that can make development easier. It will also describe how to performance RF measurements and what types of results should be expected.

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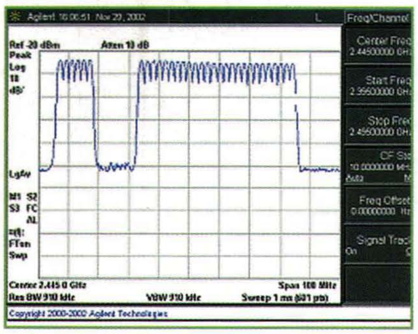
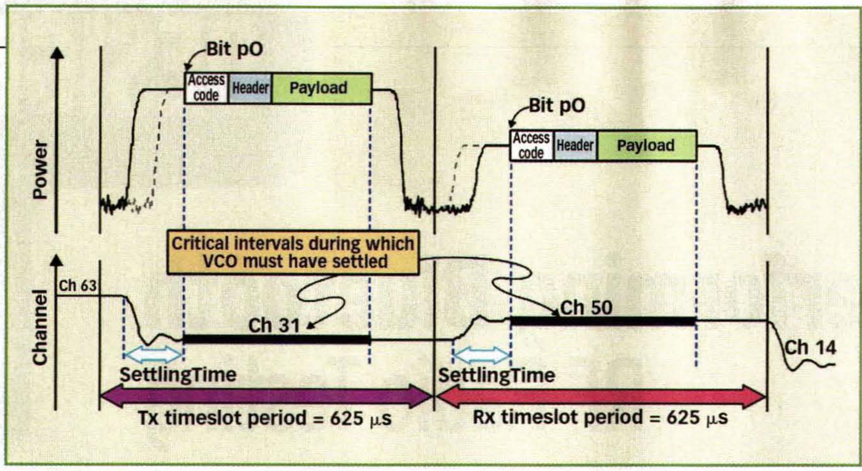


1.During the Inquiry phase, a distinct pattern may be seen, that uses only 32 of the normal 79 channels.

Bluetooth devices operate in the industrial-scientific-medical (ISM) band from 2.402 to 2.480 GHz, usually on 79 pseudorandomly chosen channels, spaced 1 MHz apart. There are occasions, such as during the *inquiry* phase, when a reduced set of channels are used. **Figure 1** shows how the spectrum usage changes during this period. Bluetooth devices communicate using a digital frequency-modulation (FM) technique known as 0.5BT Gaussian frequency-shift keying (GFSK). This means the carrier is shifted up nominally 157 kHz to represent a digital 1 value or down to represent a digital 0 value, at a rate of one million symbols (or bits) per second. The "0.5" confines the 3-dB bandwidth of the data filter to 500 kHz, thereby setting a limit to the RF spectrum occupied.

Bluetooth employs time-division-duplex (TDD) communication: the transmitter (Tx) and receiver (Rx) alternate transmissions in separate timeslots, one after the other. In addition, a frequency-hopping scheme, with up to as many 3200 hops/s during the *inquiry* phase, increases the reliability of a Bluetooth link in relatively crowded RF band. Optimum link performance is essential given that recent US Federal Communications Commission (FCC) rulings anticipate that band usage will almost certainly increase.

Figure 2 shows possible timings for sending and receiving a 366-μs DH1 packet, relative to the 625-μs timeslots. The lower traces indicate a settling-time interval. During this interval, the device must hop to the next channel frequen-



2. Several of Bluetooth's 79 channels are shown in this display of RF power envelope and VCO frequency-timing measurements.

cy and the voltage-controlled oscillator (VCO) must settle in time for the packet data to be transmitted or received. The start of the packet is not directly related to the rising edge of the RF burst, as shown by the dotted lines representing possible alternative rising edges. Nor is the rising edge of the burst related to the beginning of the timeslot. After transmission of all the packet data, the design may ramp the power down immediately, or wait until near the end of the timeslot. The exact way the burst is sent may impact other Rx designs and the battery current used.

Bluetooth Receiver Layout

An example Bluetooth Rx layout **(Fig. 3)** employs one downconversion stage (the orange boxes are areas where parts are omitted or swapped in different designs) and a single local oscillator (LO). The output of the LO is frequency doubled and switched between the receive and transmit functions. The use of FSK allows simple direct modulation of the VCO. Baseband data is passed through a Gaussian filter, which is characterized by a constant time delay and no overshoot. Pulse shaping is applied only to the Tx. Either a sample-and-hold (S/H) circuit or a phase modulator can be employed to override attempts by the phase-locked loop (PLL) to strip off phase modulation within its bandwidth. Often the IF will be quite high, to limit the physical size of the filter components and to make sure that the IF is spaced far enough from the LO frequency for proper image rejection. Antenna switching is used when the transmit level would otherwise be high enough to overloading the Rx input. Occasionally separate transmit and receive antennas are used. The reference oscillator is usually included in most combined RF/Baseband modules.

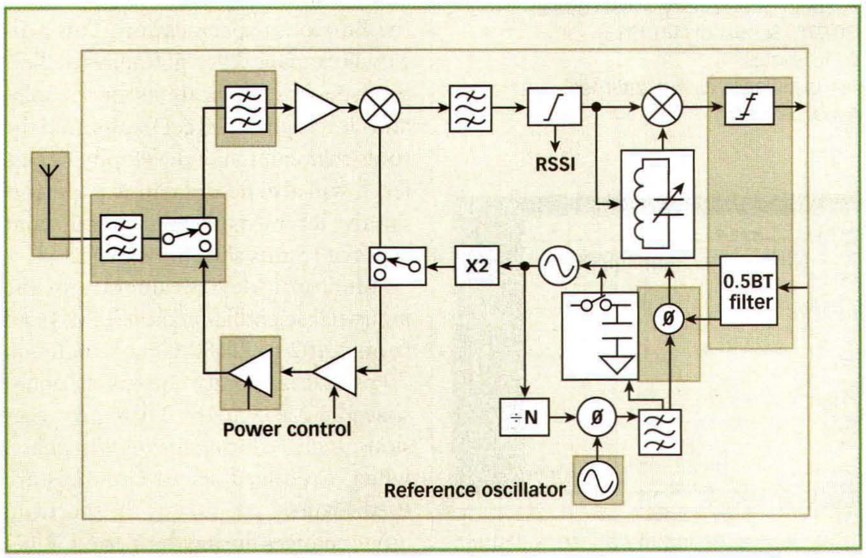
An output amplifier is optional in Bluetooth systems, but if included it will be employed to boost the power required for Class 1 (+20-dBm) versions. The amplifier's level accuracy specification is not demanding, but some attention to power output is needed to avoid excessive power output and to minimize battery drain. Regardless of whether the design delivers +20 dBm or less, the Rx must be ready to provide received-signal-strength-indication (RSSI) information, so that devices from different power classes can operate. To equalize the link budget with a non-class 1 device, it may be necessary to employ an Rx that is more sensitive than required by the basic specification. Power ramping in a design such as this can be readily achieved by controlling the amplifier bias currents, but care needs to be taken with the modulation applied during ramping, otherwise unwanted spectral components can be generated.

Bluetooth Spectrum Tests

Unlike other time-division-multiple-access (TDMA) systems such as Digital European Cordless Telecommunications (DECT) or Global System for

Methods for receiver BER measurements

DATA RECOVERY POINT	COMMENTS
Intermediate frequency	Use eye diagrams.
Demodulator output	Gate a raw PN sequence output and send BER measurement.
Baseband output	Recover clock and decoded payload data. Perform a BER measurement.
Loopback	A complete unit requires use of Bluetooth test mode; Baseband and link processing must be included. Some designs allow these tests to be performed with custom settings.



3. This schematic illustrates a direct-frequency-modulated VCO architecture with analog discriminator.

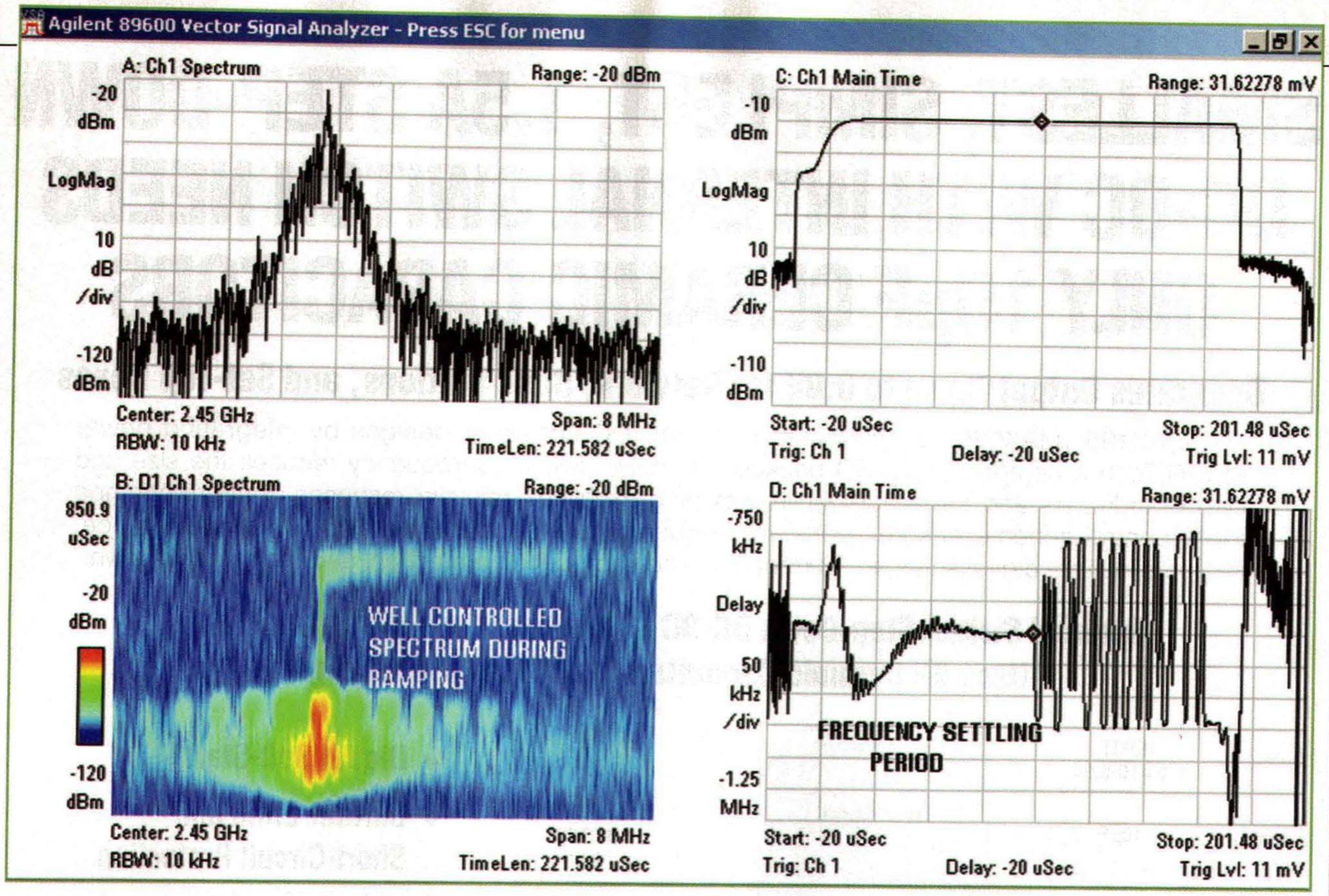
Mobile Communications (GSM), Bluetooth spectrum tests are not gated to separate out individual spectrum components. The measurement interval must therefore be long enough to capture effects due to both ramping and modulation. This may not cause certification problems, but the availability of time-gated measurements is likely to be invaluable because of their ability to quickly identify defects. An even more powerful measurement is the *spectrogram*, which shows spectrum as a function of time. As shown in **Fig. 4**, some designs make use of the unspecified period before modulation begins, usually to prepare the Rx. In this example, neither a 1 nor a 0 is transmitted.

All the frequency measurements in the Bluetooth specification rely on short gate periods. This adds noise to the results, because the narrow time window gives a higher cutoff frequency to the measurement bandwidth, thus including a variety of noise mechanisms in the measurement. An allowance for this fact will need to be made in the design limits, beyond the static error contributed by the crystal reference.

Frequency Drift

Frequency Drift measurements provide a combination of short-term, adjacent data groups, and long-term, drift-across-the-burst results. Initially this was intended to address possible S/H PLL design weaknesses. For other designs, unwanted modulation components from around 4 kHz to 100 kHz, or noise, may be viewed graphically as ripple. Setting the payload to all 1's is one way of confirming that the power supply is properly decoupled.

In the Tx path, the VCO (Fig. 2) is directly modulated. To avoid the PLL stripping off modulation components inside its bandwidth, it is either opened during transmission, or phase-error correction is applied (two-point modulation). The S/H technique can be effective, but requires care to avoid frequency drift. The phase modulator must be calibrated to avoid a lack of flatness in the modulation response to dif-



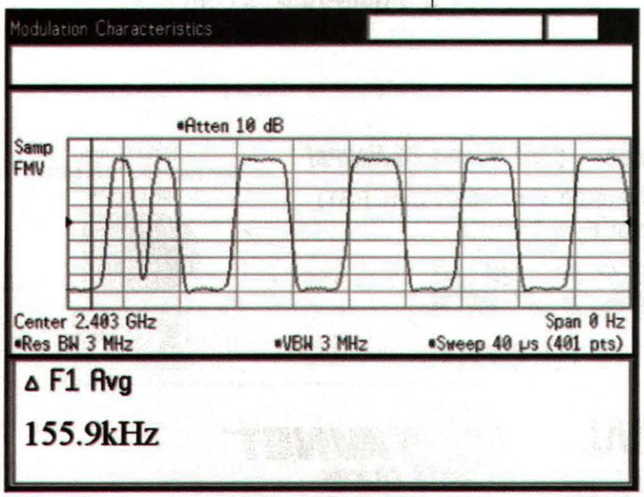
4. A spectrogram shows how the spectrum changes as a function of time during an inquiry burst.

ferent data patterns, unless a digital technique is employed to adjust the synthesizer division ratios. One of the modulation patterns used for certification tests appears in **Fig. 5.**

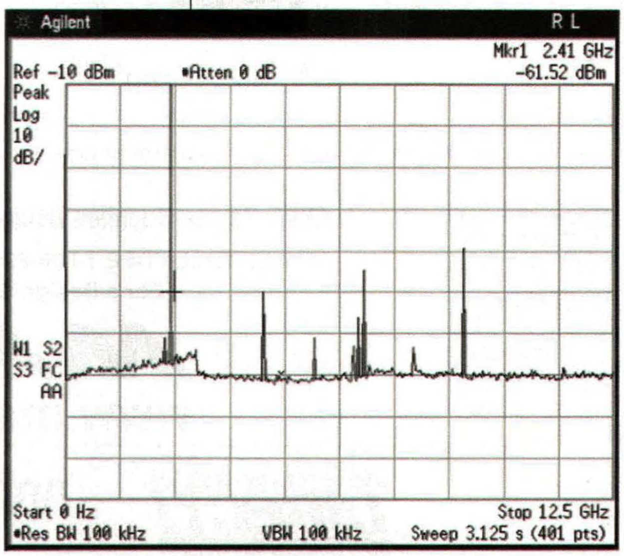
The Bluetooth RF specification checks the peak frequency deviation for two different patterns, 11110000 and 10101010. The output of the GMSK modulation filter reaches its maximum after 2.5 bits; the first pattern checks this. The cutoff point and shape of the GMSK filter are checked by the second pattern.

Ideally, the peak deviation of the 1010 pattern is 88 percent of the 11110000, although some designs transmit without 0.5BT Gaussian filtering applied and so will show higher ratios. The highest fundamental modulation frequency is 500 kHz, even though the bit rate is 1 Msymbol [=bits]/s.

The "20-dB test" confirms that a modulated and pulsed Bluetooth signal fits within a 1-MHz-wide band. Because of amplitude pulsing in the test signal, the measurement is performed with the "peak-hold" function, which makes allowance for the waveform being off the exact center frequency, by making it a "frequency-width" test, rather than just a fixed mask. The effect is very similar if the signal is centered within the mask. "Bumps"



5. This 11110000 modulation pattern is an example of waveforms used for Bluetooth certification testing.



6. A spectrum analyzer can be used to evaluate Bluetooth devices for wideband spurious content.

can appear in the spectrum due to non-datawhitened zeros or ones in the header of the packet.

The Bluetooth specification calls for adjacent-channel measurements to be performed as a series of spot-frequency measurements. An un-gated sweep is a fast, easy way to check for problems.

Frequency doubling is commonly employed to prevent RF from coupling back to the VCO, thereby causing pulling of the center frequency. Subharmonics must be removed from the RF output path, particularly if there is a danger they will affect the performance of co-sited functions.

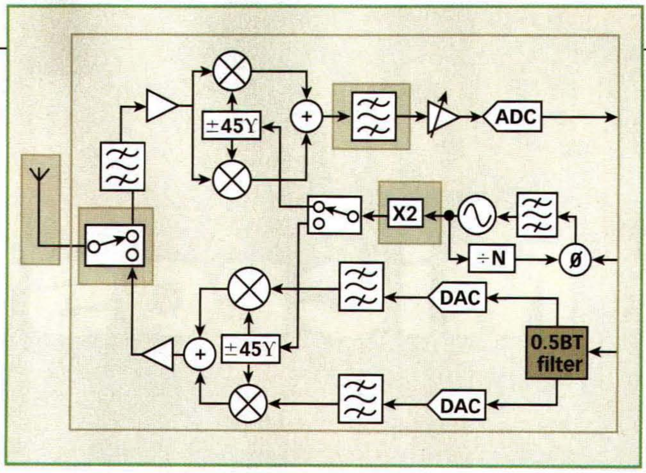
Figure 6 shows a signal from a design that exhibits no subharmonics, but with harmonics extending to 9 GHz. International regulatory specifications determine acceptable limits, rather than Bluetooth itself. Such a harmonic measurement can be performed with a standard spectrum analyzer. The 401-point sweep required 3.125 s. For investigative work, faster sweep times can be used, but they still require several seconds. If a long sweep time is chosen, newer spectrum analyzers, with deep, data-capture buffers, enable post-sweep zooming to specific points of interest.

Figure 7 shows that a number of designs have moved to I/Q mixing in both the Tx and Rx paths. This has the advantages of increasing the level of circuit integration and handling some functions with digital signal processing (DSP) rather than analog circuitry. Figure 7 depicts a hybrid approach. In some designs, image-rejection mixing is added at the front end. The high levels of silicon-level integration make this more affordable. A bandpass filter is common in the receive path.

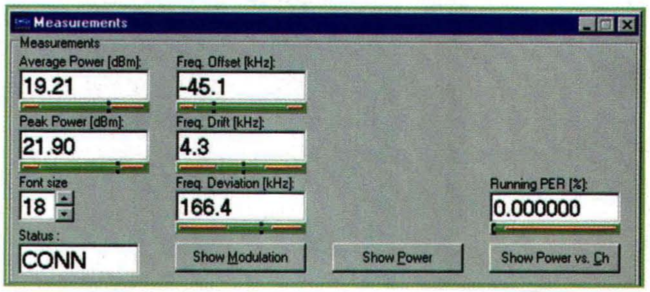
Calibration of all these I/Q stages must be carefully accounted for, because their performance may drift. Published techniques from radar and cellular applications describe sequences and signals that can be used. Fortunately for most developers, these issues are taken care of by the chip designer. Direct application of I/Q modulation to the RF output can have a surprising effect on the signal. There may be no effect from misalignment of the modulators on the "frequency" component errors, since frequency is simply the rate of change of the phase. However, it may be difficult to discern errors in the spectrum. Errors in I/Q modulation mean that there is amplitude modulation present. This can be detected by using a power-versus-time display—or by using a vector analyzer to perform more detailed investigations.

The I/Q modulator is often also used to shape the power ramp, again pointing to the potential value of gated measurements. As mentioned in the opening remarks, many forms of Bluetooth modules are found. In the receive chain, bit-error measurements will require some of the digital processing to be present before measurements are possible, or at least a level detector to act as a digital decision circuit. A zero-IF system, identified by looking for a DC block between the Rx mixer output and analog-to-digital-converter (ADC) input, may be implemented. Here, imperfections such as LO-RF feedback, which generates a DC component that

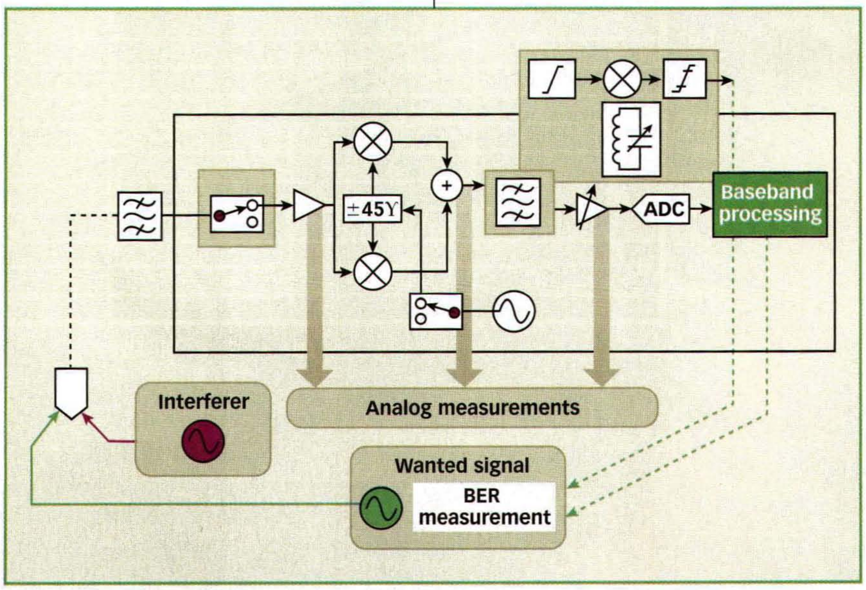
Continued on page 82



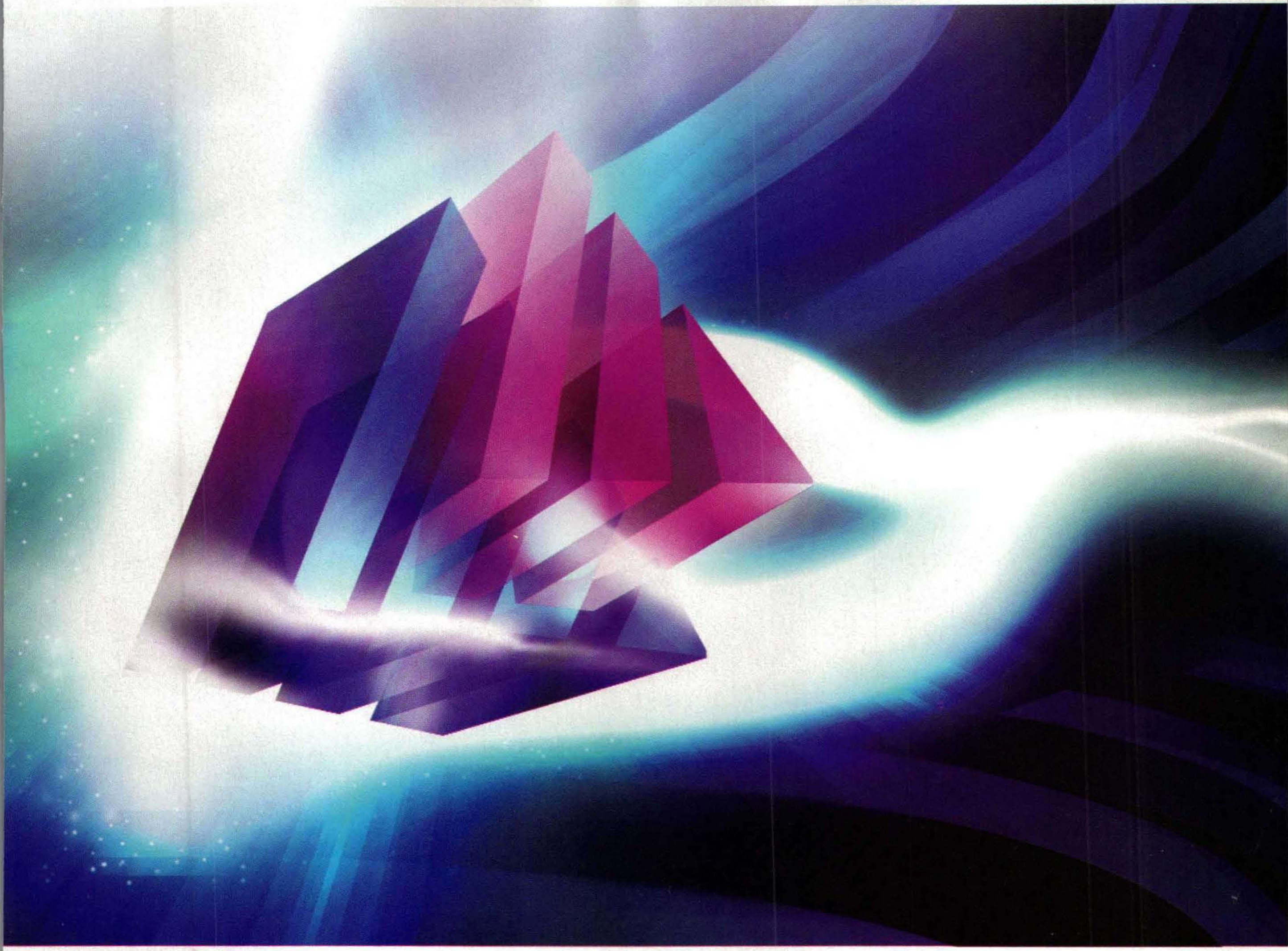
7. In this design, I/Q mixing is employed in both the transmit and receive paths, along with digital demodulation.

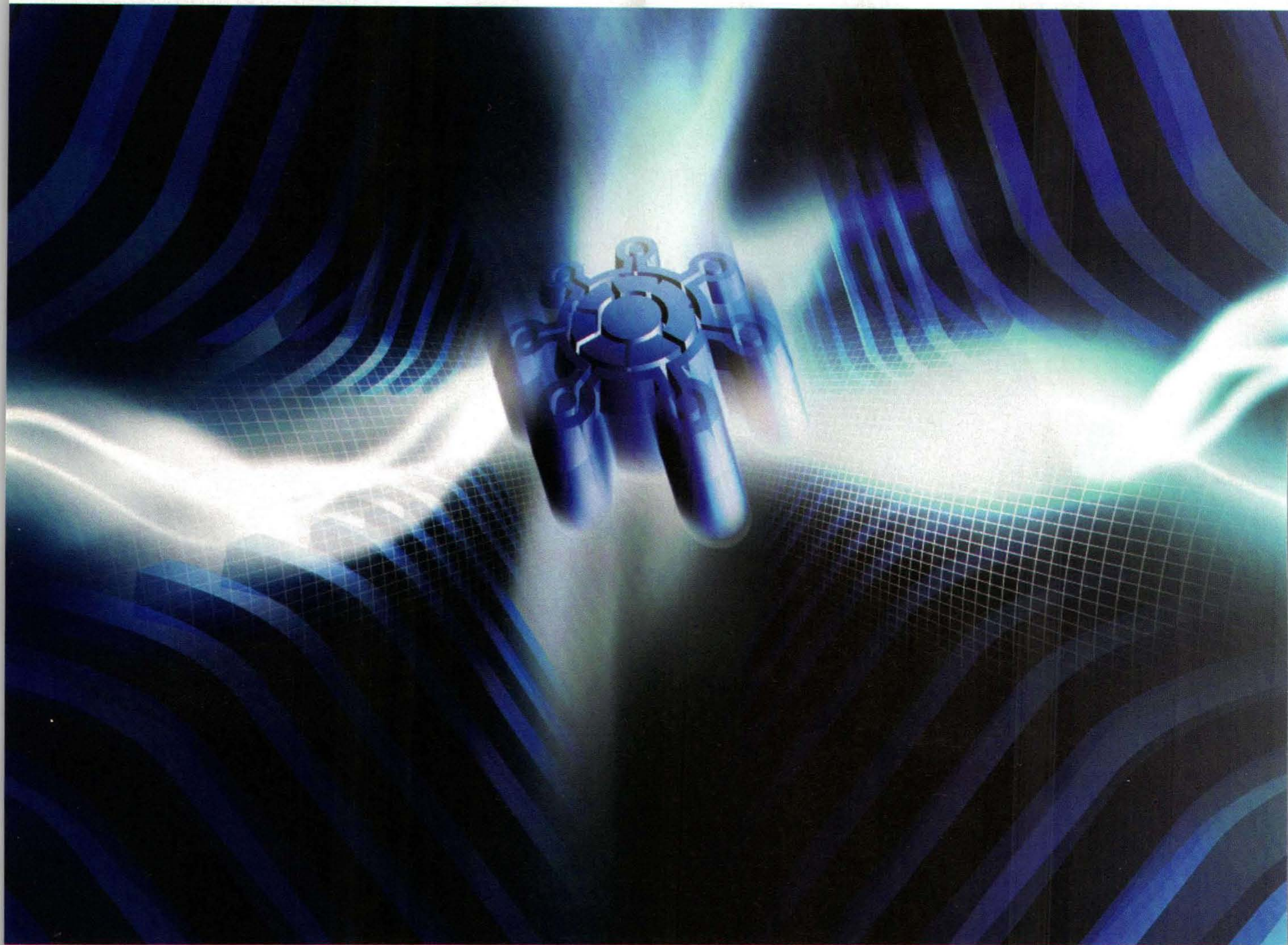


8. This screen shot shows a typical, easy-to-use interface for an integrated test set running a loopback bit-error-rate (BER) measurement.



9. Different measurement paths can be used for testing a Bluetooth receiver with and without interference.





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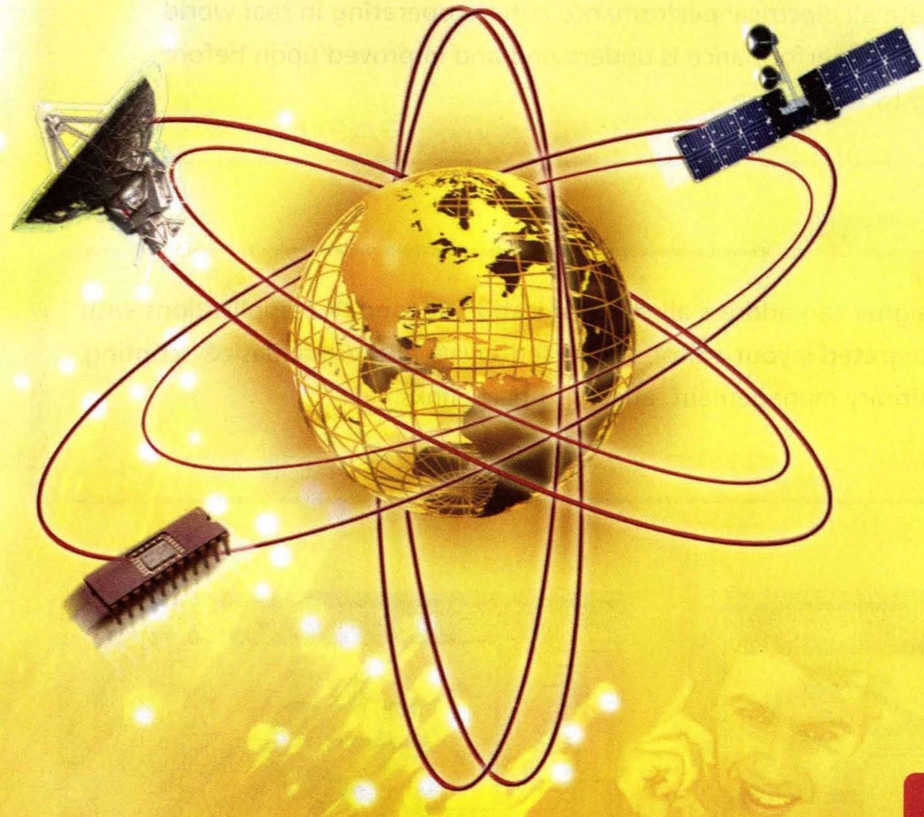

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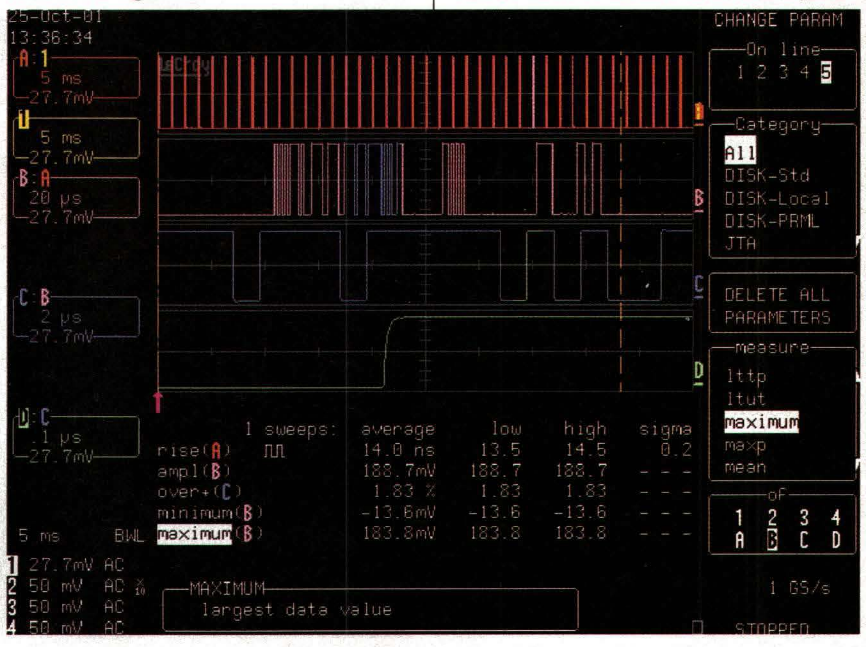
Check Bluetooth Baseband Signals With A Scope

High-speed oscilloscopes provide the capability of performing simultaneous system-level debugging and detailed large-signal analysis of Bluetooth signals.

Oscilloscopes are not commonly associated with Bluetooth measurements. But a digital scope's long memory records and multiple screen views make it an ideal tool for analyzing the packetized bursts that comprise Bluetooth baseband data. Key oscilloscope characteristics for performing Bluetooth baseband analysis include adequate memory size, sufficient number of trace displays with zoom capability, and sufficient display resolution to reveal critical information about these relative slow, real-time baseband signals.

By configuring an oscilloscope for single-time capture and acquiring a long memory record, an initial zoom trace can be used to navigate through packets in the serial data stream. At the same time, a second zoom trace can be used to isolate individual pack-



1. This screen shows a system-level view of Bluetooth baseband data. Independent zoom traces characterize physical-level, logic-level, packet-level, and bitstream-level activity within the serial data stream.

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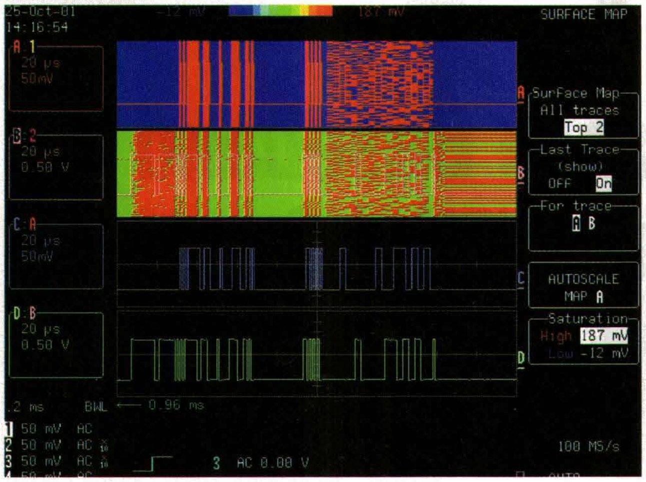
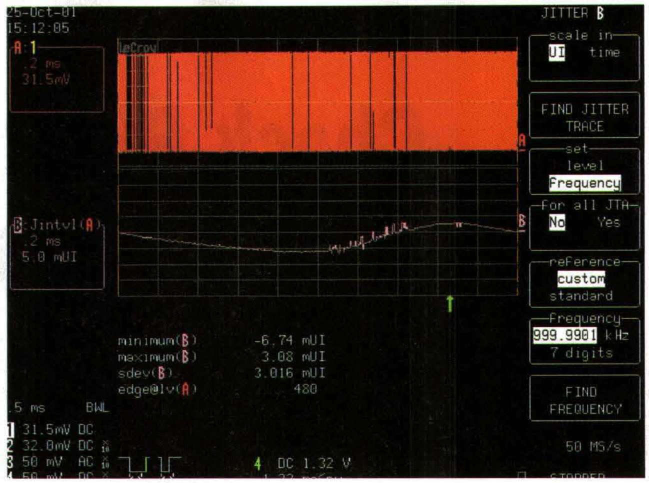


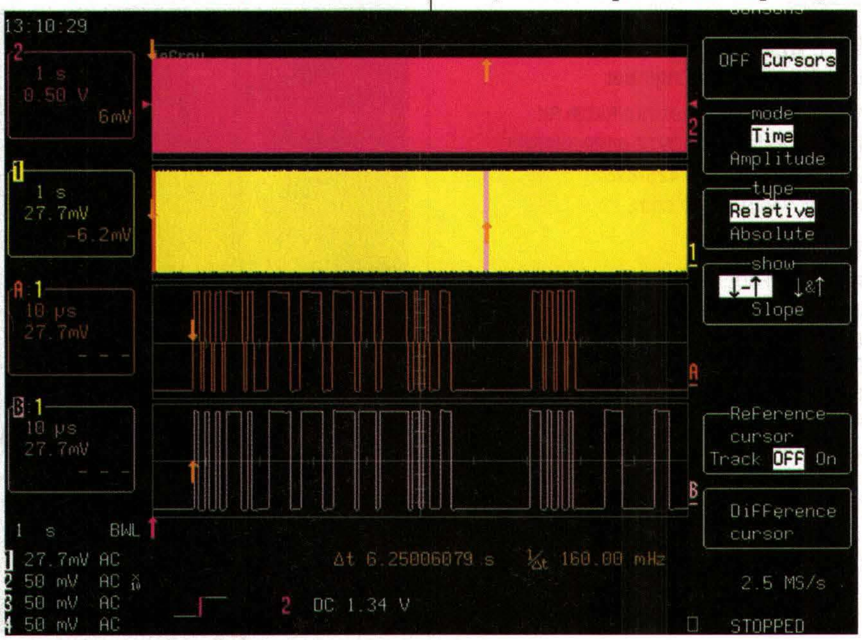
2. This surface map of transmitted and received data packets highlights constant access code, variable payload, and characteristic window size.



3. Frequency detection and time interval error of packet data reveals underlying modulation in unit intervals.

ets in order to identify the access code, header, and payload components of the Bluetooth packet structure. A third zoom trace can be used to identify specific bit values comprising the sync word, preamble, and trailer within the access code. A fourth zoom allows close inspection of physical level characteristics of isolated bits. Since the preamble is a predefined sequence, the nominal bit size can be determined by inspection of the sync word pulse width. Once this is known, the entire bit stream encompassing the access code, header, and payload can be identified on a bit-by-bit basis. Simultaneous views using a single time capture allow system-level characterization of Bluetooth baseband signals while isolating any edge of any bit within any packet in the serial data stream **(Fig. 1)**.

Captured at a slow sweep rate, the high-level interactions between transmit and receive signal lines can reveal initial verification of communication between Bluetooth devices. Transmitted data packets, poll transmissions, and null transmissions can be monitored on the transmit line, while received data packets, responses to polling, and nonresponses to null transmissions can be monitored on the receive line. An oscilloscope's ability to create a surface map of incoming waveforms allows a continuous display of the time-varying data which is useful for this verification. The amplitude of the signal is denoted by its color, where the largest amplitudes are represented in red. As the scope continuously acquires waveforms, an outline of the packet shape, and boundaries between the header and data are formed. Areas of constant waveform activity in the access code are differentiated from the dynamic variations of the payload, and the variance of logic values in the payload from one packet to the next is depicted. Note that the receive window is a different size from the transmit window as the receiver (Rx) side becomes active in preparation for possible early arrival of a packet. For a packet that arrives with nominal arrival time, we would expect to see some random bits prior to the arrival time of a packet. Surface mapping the serial bit stream allows a useful way to view signal variations in the Bluetooth baseband, identify payload and access code boundaries, and measure the transmit and receive window size. In addition, oscilloscope surface maps **(Fig. 2)**

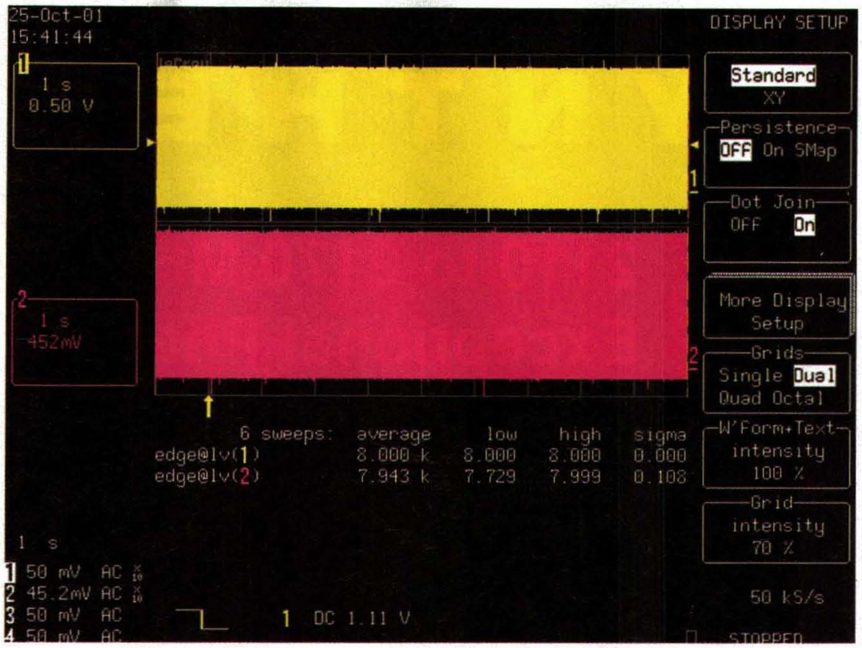


4. These timing measurements were taken on the edge of two packet preamble edges 5000 slots apart. The calculated clock drift is within the acceptable master Tx timing test specifications for the Bluetooth standard.

can be used to monitor the Universal Asynchronous Receiver-Transmitter (UART) interface and to verify that the Synchronous Connection Oriented (SCO) link between Bluetooth applications is functioning.

RF test equipment such as spectrum analyzers and vector signal analyzers is useful for making Bluetooth spectrogram measurements and for testing phenomena such as carrier frequency drift, burst profile, and frequency-modulation (FM) characteristics. An oscilloscope is able to provide unique time-domain analysis of packet data not available on other instruments such as time correlation showing cause and effect between events, measurements based on time differences between edges, and analysis of rare intermittent events.

Using a complex trigger and zoomed view of a single data packet, an oscilloscope can automatically detect the data's frequency and set an internal reference used to compute instantaneous phase changes throughout the acquisition for each cycle in the waveform. The resultant plot of time interval error reveals underlying modulation characteristics of the measured symbol timing of a packet and the jitter of the derived clock from the 1-MHz data. The resultant time interval error waveform is used to view the characteristics of the symbol timing variation. Maximum, minimum, and standard deviation values scaled to unit intervals can be computed and read directly from the oscilloscope display **(Fig. 3).**

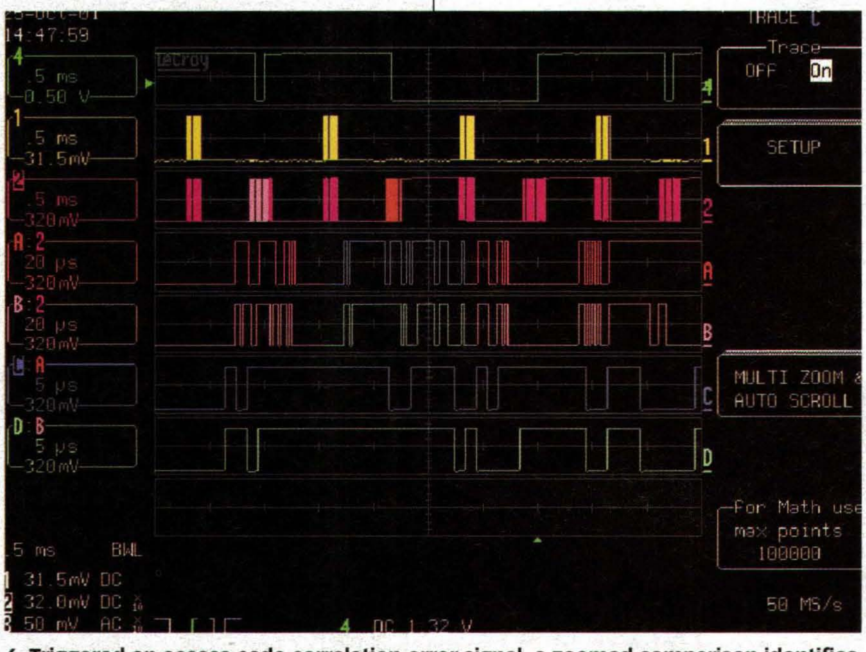


5. Edge count of master Tx sync and packet detect signals reveals packet-error rate.

The master transmitter (Tx) timing test, which is a measure of clock drift, is a difficult-to-perform Bluetooth test. The basis for the measurement is to determine that the master device will keep an exact timing interval while the piconet is active. The master is transmitting to a second Bluetooth device in the connected state, and the timing from the start of a master packet to the start of another master packet 5000 slots (6.25 s) later is measured to calculate clock drift.

The pass verdict for measured timing drift of the device under test over 5000 slots is less than or equal to 125 µs. Channel 1 is a time capture of Tx data, and Channel 2 is the Tx-on debug signal, used to signify the start-of-packet timing. The baseband transmits every other slot, with 1.25 ms per frame. Allowable tolerable clock drift is 20 PPM, which for 6.25 s is 125 µs. Capturing 10 s of continuous data using long memory and double zoom isolates two preamble pulses 5000 slots apart with a delta measurement of 6.25006079 s. This 60.79 µs measurement of drift confirms passing the master Tx timing test within the Bluetooth standard specification **(Fig. 4).**

Another difficult-to-make Bluetooth measurement is the computation of packet-error rate, which is a ratio of missed to transmitted packets. TXON is the sync for the master transmit and this signal envelopes the transmit pack-



6. Triggered on access-code correlation-error signal, a zoomed comparison identifies location of incorrect bits.

et. PKDET is the packet-detect signal of the slave and produces an edge whenever a packet is received. If there is a case of a rising edge of the master Tx sync not followed by a rising edge on the packet detect, the slave has missed a packet. The packet-error rate is the ratio of (the number of TXON edges minus the number of PKDET edges) divided by (the number of TXON edges).

Within the same time period, collecting as many edges of Tx sync as possible and using the oscilloscope to count rising edges, the ratio of missed versus sent will determine packet-error rate of the Rx. An oscilloscope's capability of counting waveform edges greatly simplifies this difficult measurement **(Fig. 5)**.

The Bluetooth baseband device can generate an access correlation signal to determine if the access code of the received packet matches the expected bit values. We want to verify that if an access code does not correlate in the baseband it is because there were errors in the received data arriving from the radio. Using Interval trigger to synchronize the scope capture to a missed packet, simultaneous zooms onto a correct packet access code and invalid packet access code quickly shows which bits in the access code resulted in the access code correlation error and missed packet **(Fig. 6)**.

The Bluetooth baseband device can generate an access correlation signal to determine if the access code of the received packet matches the expected bit values.

As has been seen, an oscilloscope can be a useful tool for analyzing Bluetooth baseband signals. As was demonstrated, the instrument can perform system-level analysis, transmission and receipt verification, master Tx timing, packet-error rate, identification of a missed packets, and the computation of time interval error. Today's digitizing oscilloscopes can provide powerful system-level analysis capabilities for debugging Bluetooth baseband systems. MRF

Achieving Antenna Isolation Within Wireless Systems

Compact antenna designs with good isolation provide improved efficiency when employed internally in handheld and portable wireless systems.

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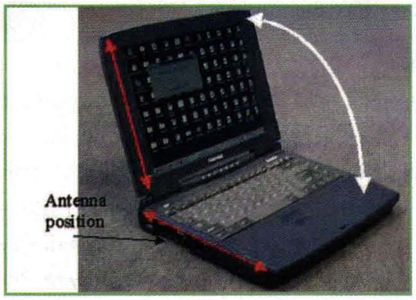
Antennas embedded within compact devices, such as handheld computers and cellular telephones, must be optimized to limit interactions with surroundings. Such antenna isolation permits good efficiency within different enclosures and reduces the engineering time needed to incorporate antennas within new enclosures. Evaluation of antenna performance can be performed on an antenna within an anechoic chamber or measurements can be made on the complete wireless system of which the antenna is a part. The isolation can then be characterized by measuring the resonance frequency shift when parasitic elements are near the antenna. Such measurements will show that antenna isolation is a critical parameter when evaluating wireless designs as part of multiple systems within the same enclosure.

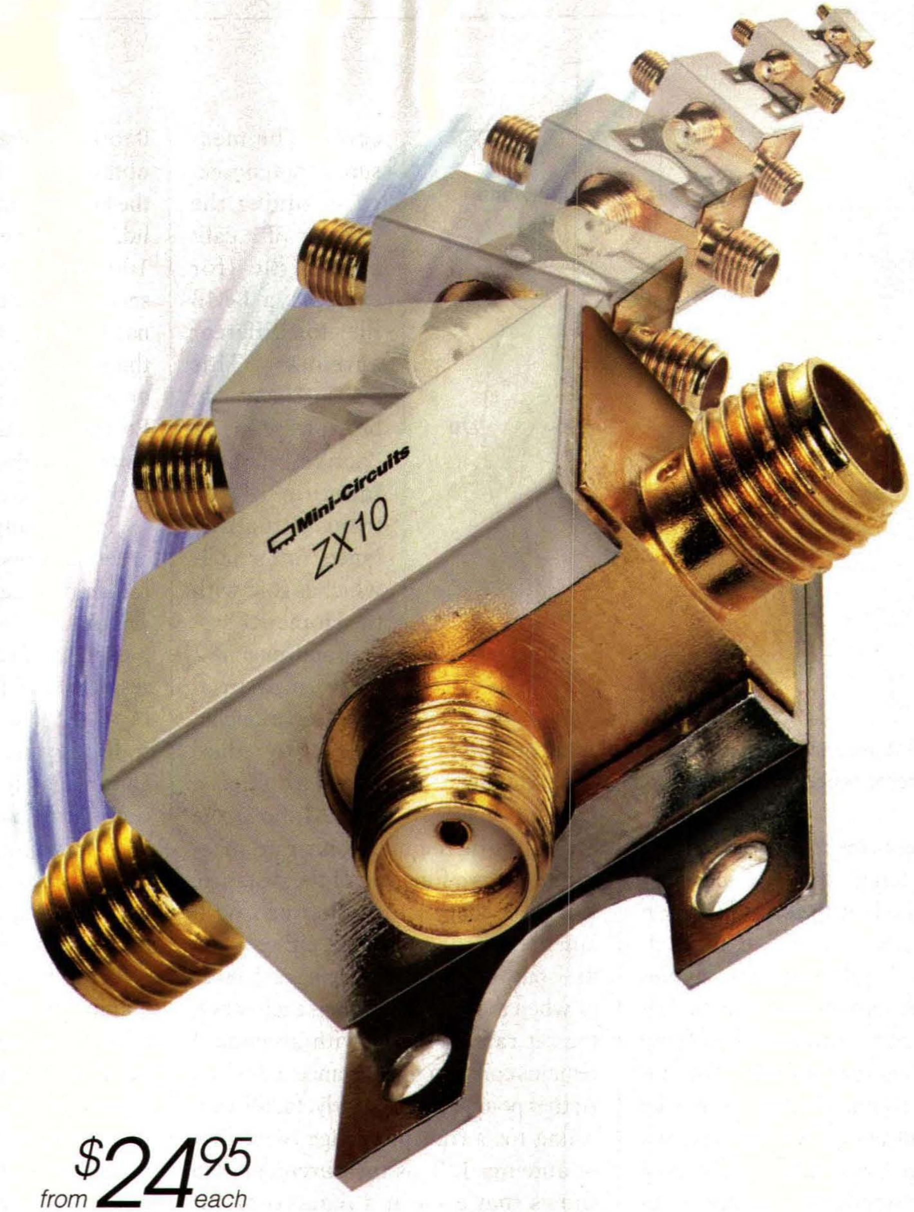
For practical reasons, multiple or multiband antennas are often implemented within the same enclosure. For efficiency and ease in integrating multi-band antennas, it is essential for their radiating elements to be highly isolated.



1. Potential resonances occur when an antenna in implemented on the side of a laptop computer.

Antennas have been studied for over 50 years.[1] Antennas radiate electromagnetic (EM) waves that interact with resonant and absorbing materials nearby, including the enclosure or package in which they are mounted.[2] This interaction can reduce the overall efficiency of an antenna, with real-world antenna patterns representing some reflections due to the interference between directly radiated antenna waves and waves reradiated by different parts of an enclosure **(Fig. 1)**. The radiation pattern of an isolated antenna can be smoothed and its efficiency improved by shaping its near-field pattern away from perturbators and absorbers. Moreover, the coupling between different antennas mounted inside the same enclosure is reduced.

An example will help to illustrate the importance of antenna isolation, based on experimental results obtained with a wireless communications system.[3] Intrinsically, antennas interact with the surroundings as they radiate the EM energy carrying the information.



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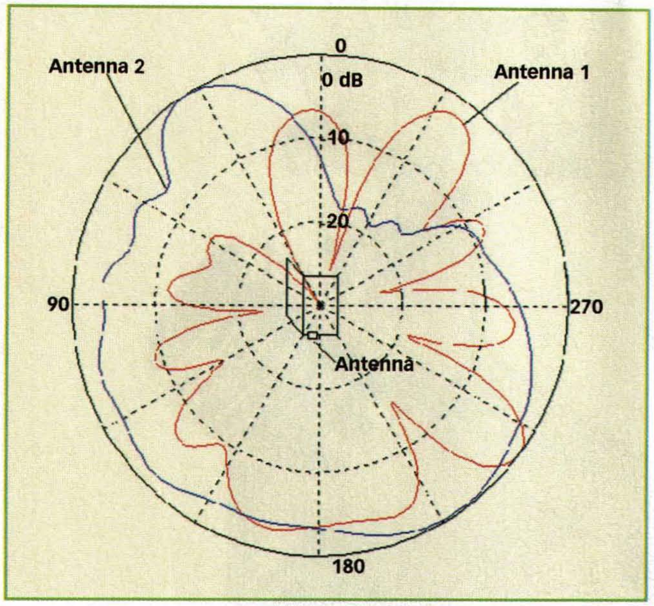


2. Two different antenna types exhibit dramatically different radiation patterns when mounted on the laptop computer.

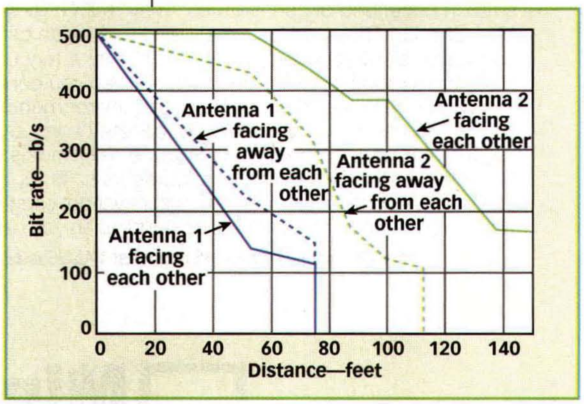
Figure 2 presents the radiation patterns from two different antennas mounted on the side of a laptop computer (as in Fig. 1). The radiation pattern of antenna 1 (a printed stub) has many ripples whereas the pattern of antenna 2 [an Isolated Magnetic Dipole (IMD) from Ethertronics] is very smooth. The ripples are due to resonances created by the near-field energy of the antenna interacting with the enclosure.[4] Part of this energy is reradiated and interferes with the direct emission in the far field. By measuring the full three-dimensional radiation patterns of both antennas and integrating the gain, it is possible to determine the efficiency difference between them.[5] Such measurements reveal 4-dB better efficiency for antenna 2 compared to antenna 1, due to a dramatic amount of EM energy from antenna 1 absorbed by the enclosure. These results indicate that antenna 2 is better isolated than antenna 1.

Anechoic-chamber measurements are sometimes critical, as the antenna mounted onto the enclosure may not be exactly as it would be mounted onto a system.[6] In the case of antennas 1 and 2, both antennas were tested with a wireless network system based on the Home-RF protocol, connected to laptop computers by means of PCMCIA cards. The measurements consisted of timing the transfer of a calibrated file (for example, a 1-MB file) for different antennas. This measurement can be expressed as an "active-bit-rate" function of the transmitted distance. Antenna 1, which is sold with the Home-RF system, and antenna 2 were measured inside a parking lot in order to reduce multipath effects. **Figure 3** shows the evolution of the active-bit-rate measurement as a function of the distance. Whereas the bit rate obtained with antenna 1 drops very fast, either when the laptop computers are facing each other or when they are away from each other, the bit rate obtained with antenna 2 remains constant to a distance of 60 feet. At that point, it drops slowly, finally vanishing for a transmit range twice that of antenna 1. This measurement also shows that even in a reduced multipath configuration, the directionality of the antenna is not critical, at least for a Home-RF system. Unfortunately, this measurement does not give any figure of merit concerning the efficiency difference between antennas.

To evaluate the efficiencies of the two antennas, another measurement setup was created. Using the same timing procedure, an attenuator was added between the RF output and the antenna. The other antenna, on the receiving laptop computer, was directly plugged into the output. Transfer times were then measured for different attenuation values from 0 to 11 dB. **Figure 4** presents the results obtained for a dipole held away from the laptop computer, over the top of the lid, corresponding to an approximate 100-percent efficiency. Figure 4 also shows the bit rate obtained with antennas 1 and 2. A linear approximation gives the efficiency difference between both antennas as 4.5 dB in favor of the Ethertronics design. This result is consistent with the 4-dB difference obtained in the anechoic chamber measurements.

This example shows that when an antenna is poorly isolated, part of the radiated energy interacts with the case. This interaction can be observed as ripples in the radiation pattern, and can result in a dramatic drop in efficiency (4 to 4.5 dB), evidenced by reduced transmission range and system bit rate. Unfortunately, these measurements are time- and space-consuming and provide only limited information. Therefore, it is necessary to define some tools to evaluate antenna isolation in a more practical way.

A key requirement for antennas used within handheld devices is minimum use of real estate. Because of the increasing number of functions and shrinking sizes of handheld devices, antennas must be mounted close to other components, especially shields. A challenge for the antenna designer is then to tune the antenna inside the enclosure, taking into account all the interactions. The tuning and the matching of a patch or a planar inverted F antenna (PIFA) depend a great deal on the near-field environment of the antenna.[7] To evaluate this



3. To minimize multipath effects, bit-rate measurements were performed on both antenna types in a parking lot.

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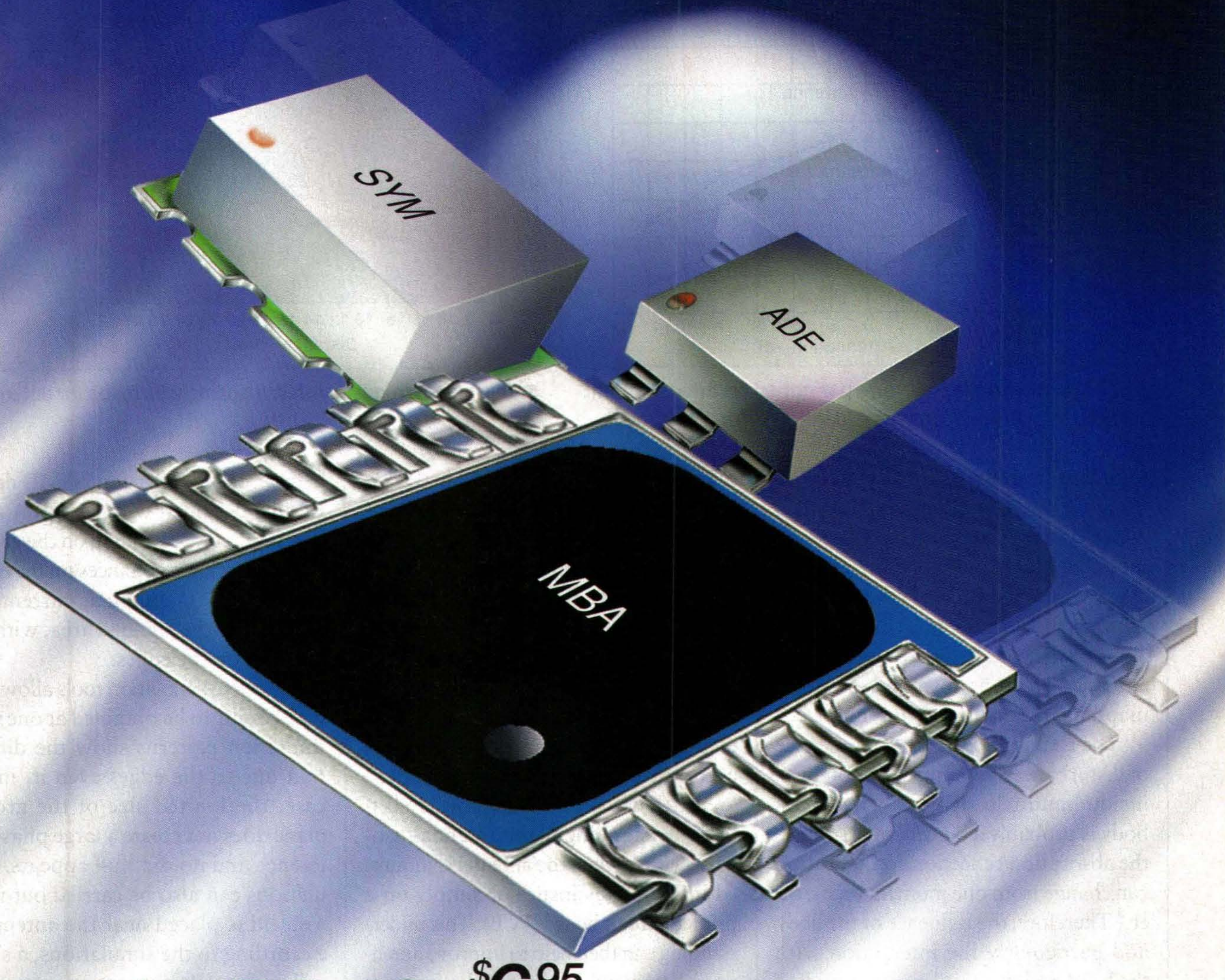

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SYM-25DMHW	40-2500	+13	26	1.3	6.6	8.95
SYM-24DH	1400-2400	+17	29	1.2	7.0	9.95
SYM-25DHW	80-2500	+17	30	1.3	6.4	9.95
SYM-22H	1500-2200	+17	30	1.3	5.6	9.95
SYM-20DH	1700-2000	+17	32	1.5	6.7	9.95
SYM-18H	5-1800	+17	30	1.3	5.75	9.95
SYM-14H	100-1370	+17	30	1.3	6.5	9.95
SYM-10DH	800-1000	+17	31	1.4	7.6	9.95

*E Factor = [IP3 (dBm) – LO Power (dBm)] ÷ 10. See web site for E Factor application note.
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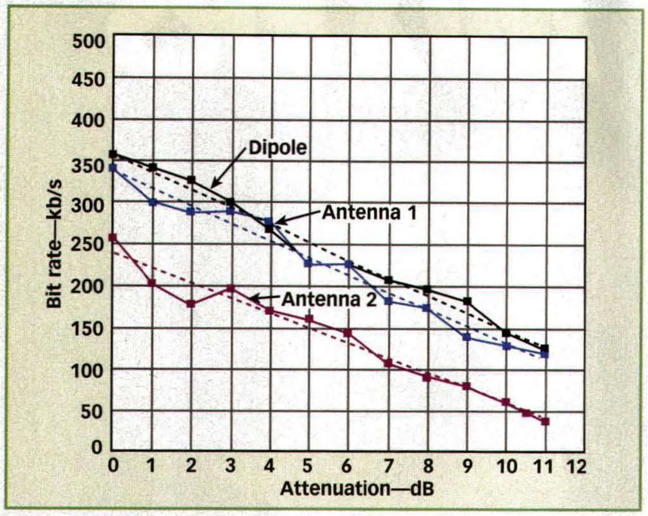
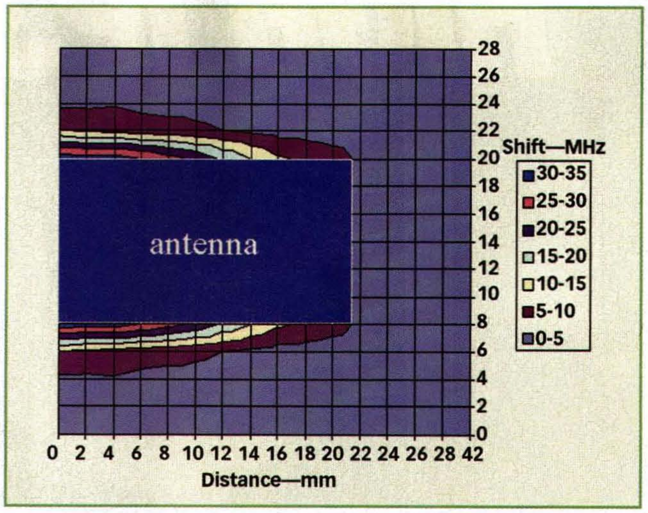


4. Bit-rate measurements were performed on three different antennas as attenuation was added.



5. This plot of frequency-shift mapping was made for antenna 2.

influence, a solution consists in looking at the resonant frequency shift when a shield is moved around an antenna mounted on a ground plane. Mapping can be obtained to show the sensitive area around an antenna. This mapping also shows isolation differences between antennas. **Figure 5** shows an example of mapping obtained with antenna 2.

The enclosure is not the only source of disturbances for embedded antennas inside handheld devices. The user's body is probably a bigger concern since the absorption/reflection configuration can change from one moment to another.[8] Therefore, the influence of the body and particularly the interaction with the head and the hand must be studied in an analysis of antennas in handheld devices. The influence of the user's head is related to the antenna's shielding, a front-to-back ratio of the radiated power in the antenna's near-field pattern. This notion is quite different from the front-to-back ratio measured on the radiation pattern, corresponding to the far-field pattern. The hand's influence is linked to the isolation of the antenna since a user's hand is placed either beside or over the antenna. Therefore, it is necessary to study the influence of the hand on the resonant frequency of the antenna. Experiments have been carried out holding a cellular telephone in different hand positions while studying the resonant frequency. **Figure 6** shows a cellular telephone in which a Global Positioning System (GPS) antenna is mounted. It also shows the return loss of the same antenna away from the hand and when the hand covers part of it. The resonant frequency does not really shift, it is mainly the matching which is disturbed, changing from –25 to –8 dB. But the antenna remains in an optimum configuration with the target GPS band even with the hand covering part of it.

Different tools can help provide a better understanding of the antenna's isolation either when the antenna is mounted inside an enclosure or simply on a printed-circuit board (PCB). This understanding can then help to improve antenna isolation and, as shown, also improve overall communications system performance. These methods are based on the current distribution analysis in the close environment of the antenna or even on the wireless device enclosure. This can be performed either numerically, using different in-house or commercial software,[9] or experimentally using the near-field measurement setup as described below.

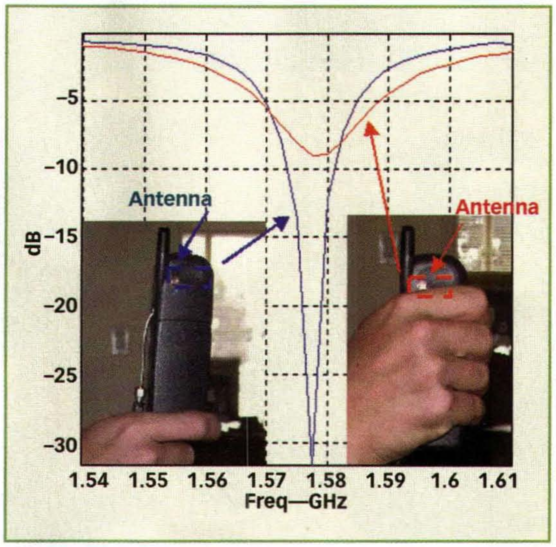
EM-simulation software is useful in antenna analysis since it can be used to estimate current and near-field distributions. By simulating an antenna on a finite-size ground plane, antenna isolation can be demonstrated. **Figure 7** shows the current distributions of two different antennas, a PIFA type and a highly isolated Ethertronics IMD design. Results obtained with the PIFA show that currents are running on the ground plane, creating resonances on the edges. With the IMD antenna, currents are confined to the antenna area, with low currents on the edges.

Software-simulation tools allow multiple results to be obtained at one time. Radiation patterns show the diffraction due to the edges even if, in this case, the limited size of the ground plane does not create a large phase difference and no dip null appears. Simulations can also be carried out when a shield is placed near the antenna.[10] According to the simulations, a shield will cause a shift in the resonant frequency for both antennas. The resonant frequency of the PIFA shifts by 9 percent, but the resonant frequency of the isolated antenna shifts only by 3 percent.

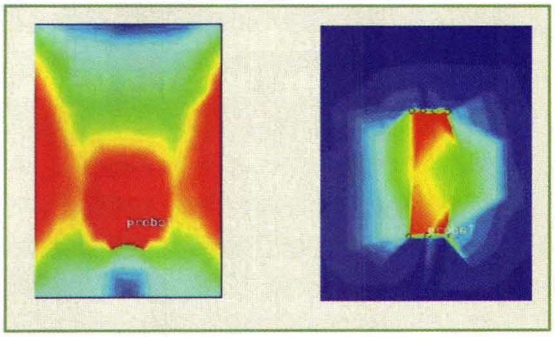
Moreover, by looking at the current distributions, the PIFA antenna shows a strong coupling to the shield. But even if some currents appear by the shield with the IMD antenna, those currents are very low. EM-simulation tools play a big role in antenna development, in order to make sure that a new design can meet system requirements, including the use of small antennas inside handheld devices supporting multiple applications with simultaneous transmission and reception.

In order to obtain experimental

results in support of the simulations, it was necessary to move a magnetic probe around each antenna.[11] For these measurements, the probe could be moved along the x-, y- or z-axis. A simple program using a GPIB interface can be written in order to move the probe near an antenna under test. The probe must be small to reduce any kind of interactions between it and the antenna under test. Using such a probe, experiments were carried out to study the current repartition over an entire cellular-telephone case. For a poorly isolated antenna, currents are running all over the case. Currents are higher on the edges of the case, as they are diffracted and create resonances in those areas. This is because part of the energy is reradiated and interferes with the antenna's direct radiation, and part of the energy will just be lost in heat inside the case. With an isolated antenna, currents are localized within the antenna area, reducing losses due to the enclosure and reducing antenna tuning/implementation time within the enclosure.



6. The influence of an operator's hand can greatly affect the return loss of a GPS antenna in a cellular telephone. The blue curve shows minimal hand influence while the red curve is the return loss influenced by the cellular telephone partly covered by the hand.



7. These two views of current distribution show the low isolation of the PIFA at left and the more restricted current distribution of the isolated antenna at right.

The first benefit of enhanced isolation is improved antenna efficiency, when an antenna is implemented within a handheld device. This greater efficiency translates into improved communication quality or better transmission range, longer battery operating lifetime, and the capability of using smaller batteries. It is also easier to tune an isolated antenna from one housing to another, potentially reducing product time to market. Finally, a properly isolated antenna can be used as a standard design for numerous handheld platforms, with only one or two parameters changing between designs. MRF

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Continued from page 60

varies with input frequency, must be carefully managed. Near-zero IF, often with the IF set at one-half the RF channel bandwidth, is more likely to be used. Then sideband suppression is an issue: a 0.1-dB gain error or 1-deg. phase error develops sidebands that are approximately 40 dB down.

By its nature, a vector analyzer can demodulate a wide range of signals. Though situations involving only directly applied frequency-shift keying (FSK) may not warrant the extra sophistication, the arguments are changing as more I/Q designs are used, or when other formats, such as Bluetooth 2, cellular radios, or wireless-local-area-network (WLAN) systems, are also being considered. Very powerful debugging techniques, such as RF data recording are now available by combining a conventional spectrum analyzer with external software.

Higher levels of integration are focusing attention on simulation tools. Not only do they enable different circuit topologies to be assessed quickly, but also the more advanced tools are able to inject a wide variety of valid and impaired signals into the Rx.

For Bluetooth, this is where some of the largest RF challenges may lie. With battery consumption in mind, the effects of restricted level-compression performance can be tested, along with phase noise, different path losses, signal impairments, and interference—including the effect of nearby Txs—as will be encountered when Bluetooth units are coupled to cellular telephones.

There are two aspects of more recent product developments that will be of significant benefit. The first is the integration of digital signal generation and vector signal-analysis blocks that provide for interchange between simulation and practical testing. Seamless links between software-analysis tools and physical test instruments allow prompt comparison of results when prototypes are delivered. The second feature is the provision of design guides that automate the set up of the tools. This provides the user with a significant boost toward using the design software for real circuit evaluations an alternative to programming in basic configuration information relating to a specific radio technology.

Front-end amplifier design and testing must focus on interference rather than the best possible noise figure or 1-dB-compression characteristics. Various published techniques are available to dynamically change gain through the Rx chain, thus optimizing the rejection of unwanted signals. Applying synchronous, pulsed amplitude modulation to the signal generator may be a worthwhile test of the burst-to-burst response of the automatic-gain-control (AGC) system, particularly if it is software controlled.

Testing the receiver of a complete Bluetooth module is done most conveniently using an Integrated Test Set. For bit-error-rate (BER) testing, a loopback signal path is created using a special *test-mode* command. Test packets received by the Device Under Test (DUT), are re-transmitted on the following burst. **Figure 8** shows a typical user interface for a such a test. This, and the other test mode commands may be sent "over the air," but the DUT should only respond to them when it has been locally set to do so. In general use, a Bluetooth device will not respond to these commands. It may, therefore, be convenient to test in "normal" mode, when a simple Packet Error Rate test is run. Although not part of the Bluetooth standard, it provides a simple indication of a good or bad device.

Loopback Test

There are several other reasons why a loopback test may not always be appropriate. The module may simply not include all the baseband control needed to establish a Bluetooth connection. Making a loopback method requires the bursts to be transmitted twice, so the test may take longer. Finally, the designer may wish to run an impairment test that is outside the scope of those contained in the Bluetooth specification. For these situations, **Fig. 9** shows measurement paths for testing a Rx in isolation, which provides maximum flexibility for the designer.

As previously noted, a common element in all Bluetooth designs is the use of a single LO. This approach, however, requires that the LO can slew across the full tuning range in less than 300 µs. This must also occur when the device is operating in Bluetooth test mode. During the transmit period, a frequency may be chosen which is at the opposite end of the ISM band to the receive test frequency, or some other arbitrary point. The LO must make the transition back to the Rx frequency each time.

Since every burst can be used for data transmission, a continuous sequence can be employed for BER testing, which may eliminate a need to perform a frequency-hopped BER test. Unless the link signaling is available, however, an operator must arrange for simultaneous control of the test signal generator and the unit under test. Once the bits have been converted to a digital format, BER testing is feasible. There are a number of ways this can be done. A summary of techniques for BER testing is listed in the **table**.

As has been shown here, standard Bluetooth measurements such as a test of Bluetooth modulation characteristics and frequency drift verify the quality of normal, but when there are failures the cause may not at all obvious. This is especially true for I/Q designs. In addition to the standard measurements, there are merits to performing non-specified measurements, such as "settling-time" and spectrogram measurements. In any case, to produce a robust Bluetooth design as quickly as possible, a radio designer should have access to a comprehensive suite of simulation and measurement tools. MRF

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Oscillators: A New Look At An Old Model

Traditional modulation theory must be updated in order to accurately analyze high-frequency oscillators in terms of spurious and phase-noise behavior.

Oscillator designers have relied on certain assumptions based on modulation theory. But by abandoning traditional beliefs, it is possible to formulate new models for analyzing oscillators. In Part 1 of this article last month, some of these long-standing conventions were shown to be less than ideal for noise analysis, leading to the development of a parameter called time inertia to explain the behavior of a resonator within an electromagnetic (EM) field **(Fig. 6)**. The discussion continued with the derivation of Eqs. 6 and 7 to define quality factor, Q, and a variable, T_0, that relates to Q and the resonant frequency.

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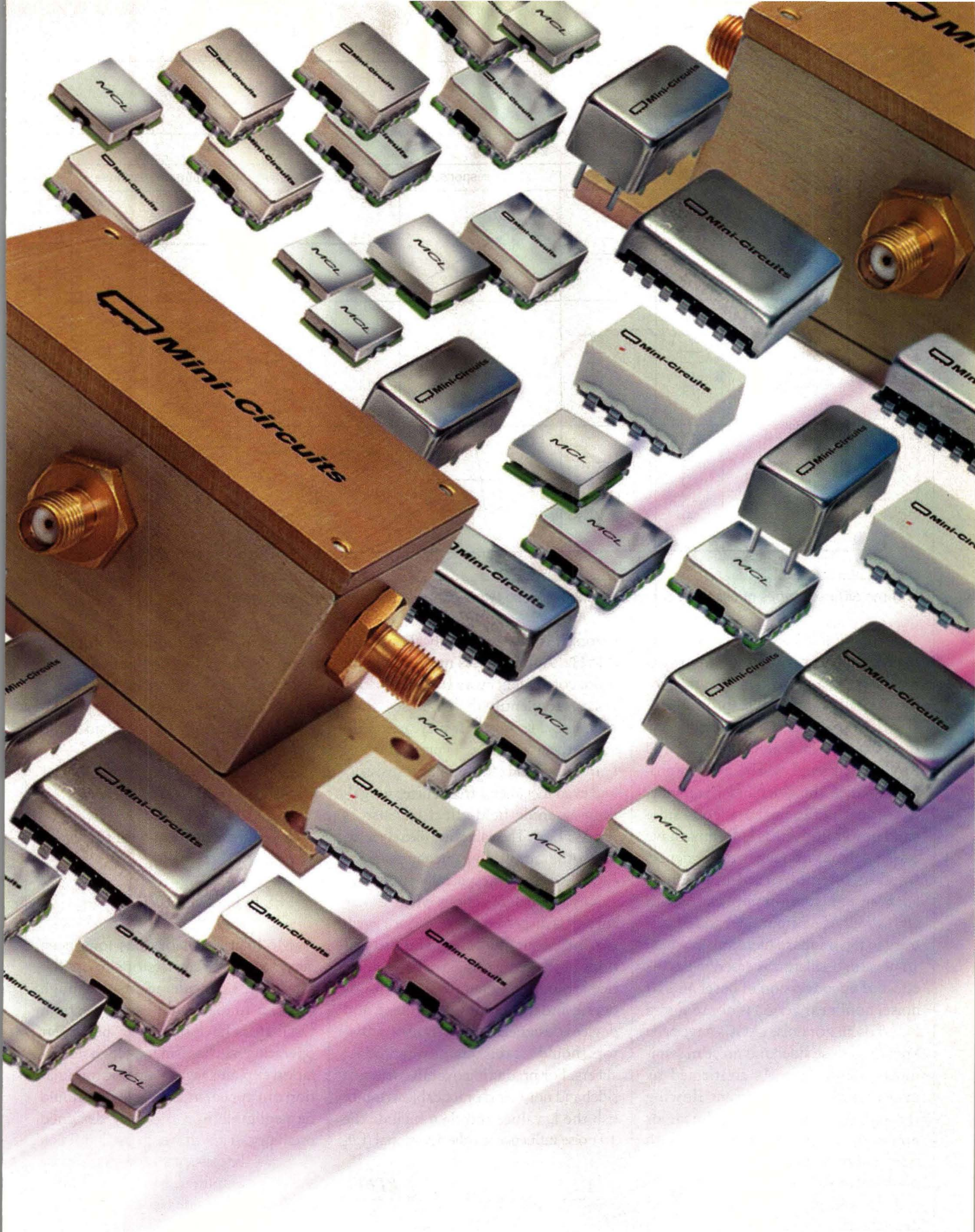
The variable T_0, expressed by τ_i, is directly applicable for such different oscillator types like LF ring oscillators with multiple inverters in the feedback loop or Gunn diode oscillators, where the transmission time through the inverter chain or the charge transit time through the semiconductor body directly determine the sideband noise level. Equation 6 makes it possible to calculate the equivalent Q for such an oscillator, where an amplitude-selective resonator does not exist. For the 100-MHz example examined earlier, the equivalent Q can be calculated to be close to 1, which is quite low. For example, well-designed wideband VCOs have an equivalent Q near 10 and, according to Eq. 7, have about 20 dB or lower sideband noise levels. Applying the same methodology to oscillators at 10 times higher frequency (1 GHz), Eq. 7 would predict noise levels about 20 dB higher for typical VCOs (at an offset frequency of 100 kHz), around –110 dBc/Hz.

The measured noise seems to be "white" in nature, i.e., having a flat, thermal kT density. Only at very low frequencies (acoustic range) does its behavior essentially change. As the measurement frequency decreases, the noise level increases according to the 1/f rate of noise power (10log/decade). The phenomenon appears not only with DC current, but also with any AC current, always exhibiting 1/f slope sidebands. For any generated frequency having f^{-2} sidebands according to the very oscillator action, as was described earlier, it adds its own impact, resulting in the f^{-3} (–30 dB/decade) sideband noise slope, close to the carrier f_0. Despite experimental results, this phenomenon still remains a mystery. A possible explanation is that any current flowing through any physical material excites 1/f power sidebands. So, the spectrum of any real current may not be abrupt, but must essentially have a smooth, 1/f slope. Any dislocations or impurities within the material will create traps for charge flow.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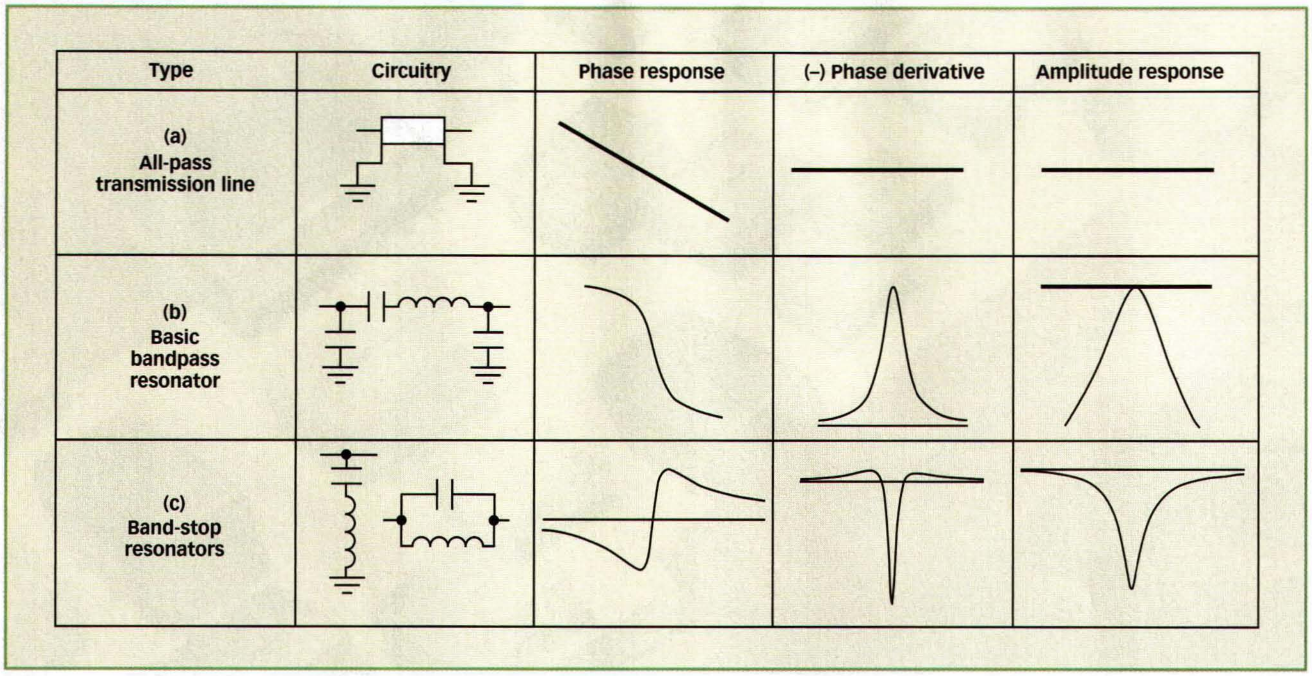

6. Three different types of oscillator resonators exhibit these types of phase and amplitude responses.

Defining sideband resistance, R_s, as the resistance presented for an instantaneous sideband frequency, f_s, it is evident that its value will be proportional to the trapping or sideband frequency. If so, than an instantaneous sideband frequency current I_s will be inversely proportional to the sideband frequency. Accordingly, the instantaneous sideband power P_s given as $I_s^2R_s$ must have a 1/f sideband frequency dependence, which is often observed in practice. Such an explanation applies to both DC as well AC current sidebands. Contrary to the standard literature in which 1/f noise in oscillators is described as the effect of upconversion of baseband 1/f noise, nonlinear action is not required for 1/f oscillator noise (AGCs have been known to raise sideband noise in semilinear oscillators). As confirmed by measurements, any current flowing through a device, whether linear or nonlinear, excites 1/f sidebands, with sideband power density proportional to the current value.

It should be possible to describe the 1/f noise level for a device at given conditions in practical terms, for example at a 1-Hz sideband frequency. For bipolar transistors, this level is typically about –120 dBc/Hz. Another (less meaningful but more convenient) way to describe this noise is to identify the 1/f noise corner frequency, f_c, where it increases 3 dB above the noise floor. Typical values of f_c are near 5 kHz for bipolar transistors and even megahertz frequencies for gallium-arsenide field-effect transistors (GaAs FETs). The values are directly related to the amplifying mechanism for each device type, especially to its sensitivity for surface actions where device current is dispersed due to surface irregularities, contamination, and dislocations in the semiconductor crystal lattice structure. Generally, 1/f noise is device and technology dependent, and devices designed for low-noise oscillators should list this quantity in product sheets. For predicting overall oscillator sideband noise, it is practicable to establish the f_c value, and then include the 1/f noise influence, by the additional (f_c/f_s + 1) term which modifies the noise floor. Applying that component to Eq. 4, including noise plateau, and taking into account the generalized τ_i parameter, leads to the complete sideband noise form:

SEE EQ. 8 BELOW

Its equivalent form with Q instead of τ_i is:

SEE EQ. 9 BELOW

Modulation theory has long been accepted as the cornerstone of oscillator spectra considerations, although this is a fundamental misconception. Oscillators have their own particular operating mechanism, in which modulation explains little. Parasitic modulation can appear at any time, but should be negligible in a properly designed oscillator. If anything, an oscillator can be considered as a special noise amplifier. More specifically, it is a "phase-selective," infinite-gain, noise amplifier that produces a very narrow and symmetric "burst" of noise. Phase-selective means that the oscillator loop phase zero-

$$N_S = \left(\frac{1}{\omega_S^{2}\times\tau_i^{2}}+1\right)\times\left(\frac{f_c}{f_s}+1\right)\times\frac{kTFG}{P} \quad (8)$$

$$N_S = \left(\left(\frac{f_0}{f_S\times 2\times Q}\right)^{2}+1\right)\times\left(\frac{f_c}{f_S}+1\right)\times\frac{kTFG}{P} \quad (9)$$

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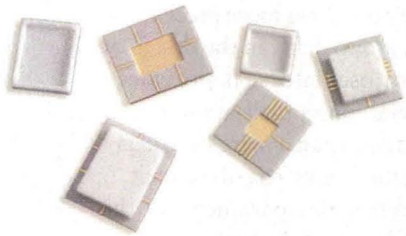

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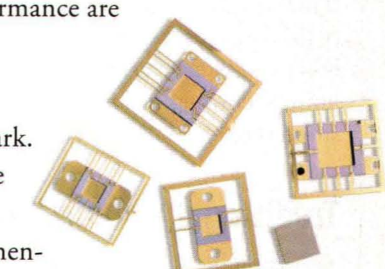

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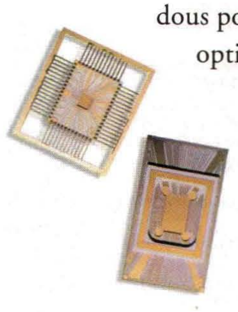

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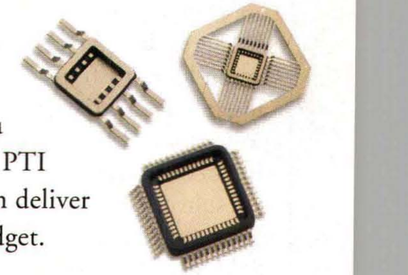

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crossing point determines the oscillation frequency, while its quality is determined by the phase characteristic slope at this point. In general, the amplitude characteristic is irrelevant for oscillation analysis, although amplitude selectivity can be very desirable for secondary reasons. The natural coexistence of both phase and amplitude responses of resonance circuits makes it possible to confuse their roles. Proper distinction is possible when general cases with transmission-line oscillators, as well as inverted amplitude responses, are considered.

The close-to-the-carrier spectrum (discerned from harmonics) should always be considered as one entity, without separation of the carrier from the sidebands. Only in subsequent system stages it is justifiable to approximate an oscillator's spectrum by a single spectral line. An oscillator's signal sidebands have an inherent f^{-2} slope, while their level (signal quality) is determined by the instantaneous loop phase derivative. The natural measure of generated signal quality is sideband noise density (SND). This parameter is commonly in use, although it has been called phase noise according to improperly understood theory.

Traditional Visualization

Traditional visualization of generalized signal sidebands with several descending power-law sections on log-log diagrams leads to another common misunderstanding. As it was shown earlier, the oscillator action yields only a f^{-2} sideband slope. However, any currents flowing through a physical structure excite sidebands of 1/f power density slopes which add to the sideband slope, resulting in a common f^{-3}slope at the lowest offsets. There are two possible transitions down to the flat noise floor. The traditional explanation of oscillator 1/f sideband noise, as a result of upconversion from baseband, cannot be justified. DC as well as AC currents excite inherent 1/f sidebands, because of microstructural irregularities, thus causing elementary charge trapping, especially within semiconductor devices with significant surface action.

Oscillator quality has traditionally been categorized as short-term and long-term stability, without any transition between the two. The meaning of long-term stability or instability is easily understood with such influences as temperature, humidity, aging, vibration, etc. Short-term stability is erroneously based on modulation theory to explain oscillation behavior. But, as has been shown, it is not correct to apply the terms stability or instability in regard to oscillator sidebands. It is more accurate to make the connection to the selectivity of the oscillator as an active noise filter. The term "low-noise oscillator" should be used instead of saying an oscillator with good short-term stability.

The parameter for the phase-response derivative provides a more precise concept than group delay in the design an analysis of oscillators. It provides a more general conceptualization of oscillator behavior than a mere time delay, reflecting the EM inertia of a circuit. In understanding this parameter in this way, problems are eliminated in terms of possible negative values as well as with determining it at an instantaneous frequency points. MRF

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Design A High-Precision Antenna For GPS

Proper modeling using an FEM electromagnetic simulator leads to the design of a low-cost, lightweight GPS patch antenna capable of excellent multipath rejection.

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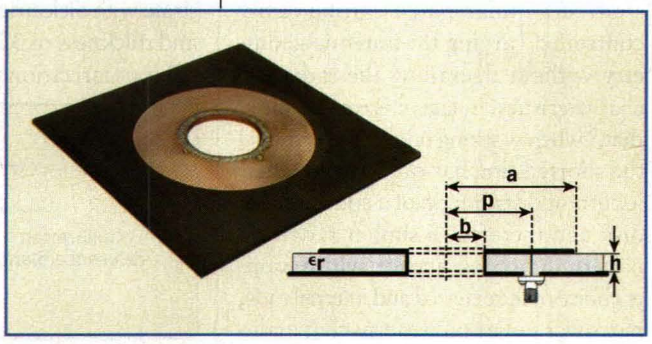
Global Positioning System (GPS) receivers (Rxs) are becoming ubiquitous, as part of the electronics packages of new automobiles, in cellular telephones, and in compact electronic devices. Unfortunately, multipath errors continue to plaque the performance of discrete and embedded GPS Rxs, even with advances in signal processing. However, an innovative low-profile, lightweight antenna may offer a possible solu-tion for reducing the multipath error in GPS systems. As will be shown, it may be possible to achieve high-performance GPS requirements with the aid of a shorted annular patch antenna.

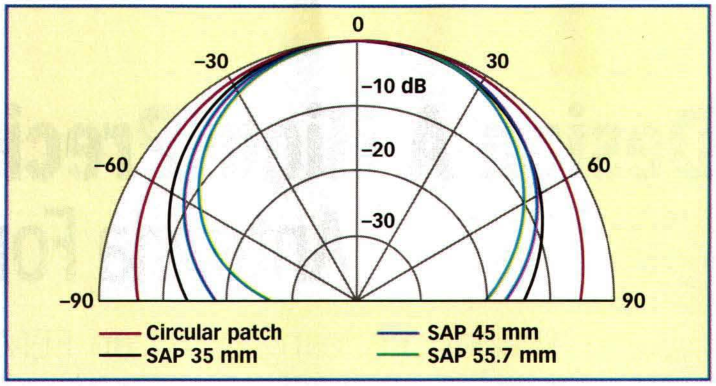
In recent years, the number of GPS applications requiring an augmented accuracy is considerably increased spanning from geodetic surveying to aircraft landing control and satellite attitude determination. The major limitation affecting the precision of the system is the multipath error. Multipath interference is generated by the reflections and diffractions of the GPS transmitted signal from surfaces around the antenna. Since multipath effects are dependent upon the surrounding environment, they are difficult to quantify, and available signal-processing techniques do not help in solving the problem completely under all conditions. A more effective way to limit the deleterious effects of spurious reflections is by means of an antenna with superior multipath rejection capability.

At the radiator level, multipath can be essentially controlled in two ways. Since GPS signals are right-hand circularly polarized (RHCP), odd reflections are left-hand circularly polarized (LHCP). Hence, the use of antennas with a good rejection of LHCP signals can potentially eliminate multipath effects arising from direct reflections. Effects due to double reflections will remain, but these are normally much



1. This cross-sectional view shows the inner radius and feed locations (a, b, and ρ) of a shorted-annular-patch (SAP) antenna.

weaker than the direct reflections. Additionally, considering that reflections often impinge on the antenna at low elevations, multipath rejection performance can be improved by shaping the antenna gain pattern to reject low-elevation signals while ensuring adequate hemispherical coverage.



2. The SAP antenna offers a great deal of radiation pattern flexibility.

Several low multipath GPS antennas have been proposed in the past. Unfortunately, most of the available solutions, including arrays[1] or choke rings,[2] are impractical in aerospace applications due to the operational requirements in terms of size and weight. A more effective design has been proposed in ref. 3 where a novel compact radiator, namely the shorted-annular-patch (SAP) antenna, has been introduced as a possible solution for low-multipath GPS applications. In what follows, the main characteristics of SAP antennas will be discussed and a detailed review of a SAP design procedure will be presented.

The SAP antenna geometry is presented in **Figure 1**. At variance of a conventional disk the inner boundary of this patch is shorted to the ground plane. The presence of the conductor in the central zone of the antenna makes this geometry much more flexible with respect to other microstrip geometries allowing for a larger bandwidth and easier matching.[4]

The essential feature of the antenna is that the low-multipath radiation pattern requirements can be fulfilled using a single radiator, as the pattern of the shorted annular patch can be easily controlled varying the antenna geometry without degrading the radiation characteristics. In fact, it is easy to show that,[5] when working on the TM_{11} mode, the shorted ring has the same magnetic current distribution of a conventional disk and therefore a similar radiation pattern. As a consequence, with a proper choice of the external and internal radii, narrower radiation patterns that maintain the radiation characteristics of a circular disk can be obtained.

To design an SAP antenna, the first step is the selection of the patch outer radius. As it will be shown, this parameter essentially controls the antenna amplitude pattern toward the horizon and, in case of high-precision GPS applications, its choice must be the optimal compromise between the specific coverage requirements and the low multipath constrains. Once the external

Inner radius and feed locations of the three antenna patches

a	b	ρ
35.0 mm	6.0 mm	12.0 mm
45.0 mm	18.83 mm	25.0 mm
55.7 mm	30.08 mm	36.5 mm

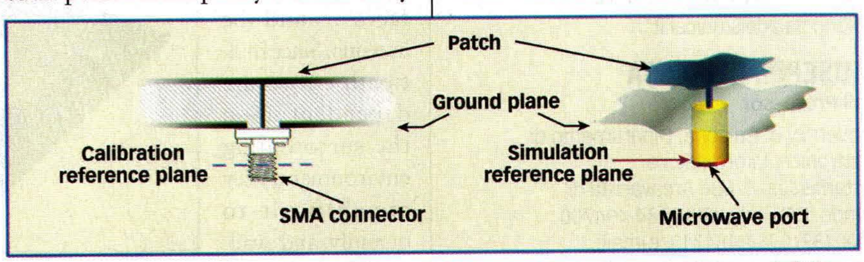
boundary of the shorted ring has been fixed, the inner radius has to be adjusted to make the patch resonating at the desired frequency.

As a proof of the SAP peculiarity, three shorted annular patch antennas resonating at the nominal GPS L1 frequency, 1.57542 GHz, with an external radius of 35, 45, and 55.7 mm, have been designed considering a substrate with dielectric constant, ϵ_R, of 2.55 and thickness of 3.2 mm. Adequate circular polarization purity is attained by feeding the antenna by means of two 50-Ω coaxial probes located 90 deg. apart and having 90 deg. of phase difference.

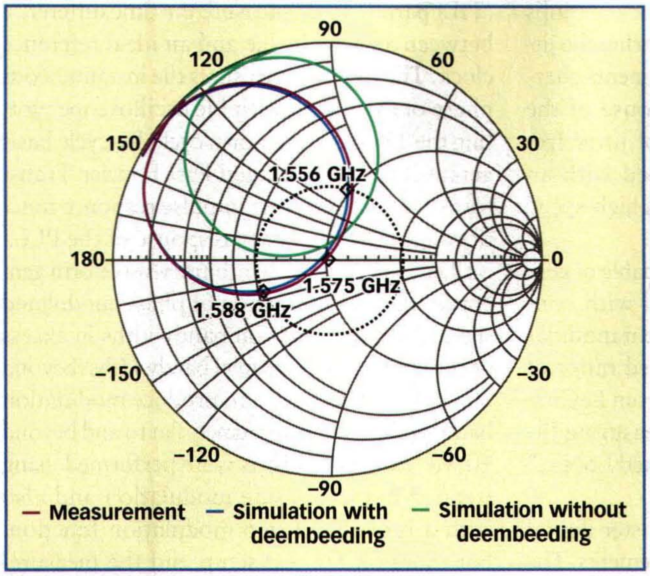
To simplify the design process, a simple analytical model[4] was used as a starting point to roughly estimate the antenna resonant frequency and feed location. The design was then optimized through extensive finite-element-model (FEM) based simulations using commercial High-Frequency Structure Simulator (HFSS) software from Ansoft Corp. (Pittsburgh, PA).[6] Accurate simulations were obtained by manually refining the mesh for each geometrical element of the antenna. The inner radius and the feed location for each of the three patches are shown in the **table**.

The effect of a larger external radius is shown in **Fig. 2** where the copolar radiation patterns of the three SAP antennas have been compared with the one of a conventional circular patch resonating at the same frequency and designed using the same substrate. As expected, a larger outer radius of the antenna results in a narrower beam.

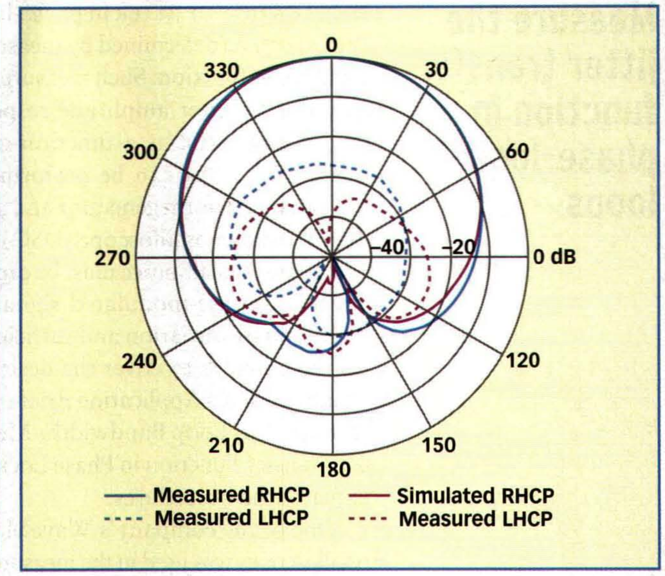
It should be noticed that the shorted annular patch antenna having external radius of 55.7 mm was designed by considering the surface's wave reduction principle described in ref. 5. According to this criterion, the outer radius of the ring must be selected in such a way that the TM_0 surface-wave emission is inhibited avoiding the radiation pattern deterioration due to the diffraction of the waves on the dielectric truncation. However, the choice of the external radius is also influenced by



3. This diagram shows the simulation and measurement reference planes used for comparing results.



4. This comparison shows the modeled and measured input impedances of the SAP antenna.



5. This is a comparison of the measured and modeled radiation patterns for the SAP antenna.

other requirements such as the extension of the radiation pattern coverage and the acceptable level of crosspolar interference.

The characteristics of the antenna and the reliability of the simulations were experimentally verified fabricating a prototype of the SAP antenna having an external radius of 35 mm.

The simulated and measured input impedances of the antenna were first compared. A comparison between numerical and experimental data often serves as a source of errors, however, due to false assumptions or poor estimations. In this case, in particular, it should be noticed that the measured input impedance is generally taken at a reference plane arbitrarily set during the calibration while the computer-generated data are calculated at the microwave port defined within the simulation environment **(Fig. 3)**.

To avoid this phase uncertainty, the two results presented here have been compared choosing the antenna ground plane as the common reference. The calibration reference plane was set by measuring and analyzing in the time domain the reflections arising from a short-ended SMA connector of the same type of the one used to feed the antenna. The calculated input impedance was coherently evaluated at the antenna ground plane by employing the de-embedding procedure included within the simulation tool environment.

In **Fig. 4**, the measured antenna input impedance is compared with the simulated data before and after the deembedding procedure was applied. As it can be seen, the predicted result is in excellent agreement with the experimental values but this outcome can be appreciated only if a coherent de-embedding method is used.

Due to the precision of the simulator and the accuracy of the fabrication process, it was possible to achieve a fairly precise design that provided predictably high performance. In fact, the antenna resonates at the nominal GPS L1 frequency and is very well matched. The multipath rejection performances of the SAP prototype have been evaluated considering both the sharpness of the antenna pattern toward the horizon and the circular polarization purity over the whole radiation hemisphere.

The measured and simulated radiation patterns **(Fig. 5)** show that the proposed SAP antenna has, as expected, an amplitude roll-off from boresight to horizon of about 15 dB. It is important to note that this result, which provides a wide hemispherical coverage while sufficiently rejecting grazing signals, has been obtained using a 14-cm-square ground plane so without increasing the overall dimension of the antenna. In addition to the sharpness of the radiation pattern, the SAP prototype proposed in this paper fully satisfies the polarization purity constrains required for high-precision GPS applications. In fact, the axial ratio stays below 2 dB within the entire coverage hemisphere.

The final antenna design, based on an SAP geometry, is inexpensive and light in weight, but offers an extended radiation pattern flexibility which can be used to optimize the multipath rejection performances in consideration of the specific application constrains. The characteristics of the antenna have been verified performing both numerical and experimental tests. Where properly considered, the simulated results are in excellent agreement with the experiments. MRF

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Measure the jitter transfer function in phase-locked loops

PROPAGATION OF JITTER in phase-locked loops (PLLs) can be determined by measuring the jitter transfer function. Such measurements characterize the jitter amplitude response of the device under test as a function of jitter frequency. The test can be performed with an arbitrary waveform generator and a high-speed digital storage oscilloscope (DSO).

The test signal source must be capable of generating a phase-modulated signal with controlled phase deviation and sufficient modulation bandwidth to cover the desired range of frequencies. An Application Brief from LeCroy Corp., "PLL Loop Bandwidth: Measuring Jitter Transfer Function in Phase Locked Loops," explains the procedures.

One of the company's WaveMaster digital oscilloscopes was used in the measurements. The instrument is equipped with the XMAP extended math option, which includes the jitter and timing analysis measurement parameters used in the example. The measurements are performed with the aid of one of the company's LW420 arbitrary waveform generators, and using the digital oscilloscope's time-interval-error (TIE) parameter to measure the time difference between an signal edge and an ideal reference clock. The function measures the instantaneous phase of the signal, with the oscilloscope plotting the TIE parameter on a cycle-by-cycle basis versus time. An averaged Fast Fourier Transform is used to convert impulse response functions into the frequency response of the PLL.

The LeCroy LW420 arbitrary waveform generator allows the creation of phase-modulated signals with modulation bandwidths in excess of communications channel bandwidths (beyond 10 MHz). The source can produce modulation bandwidths that are extremely flat to and beyond 10 MHz in width. Tests were performed using stepped frequency sine modulation and also with a broadband step modulation function. For more on the test setup and the measurement technique, request a copy of the application note, free of charge from LeCroy's website.

LeCroy Corp., 700 Chestnut Ridge Rd., Chestnut Ridge, NY 10977-6499; (845) 425-8967, FAX: (845) 425-8967, e-mail: contact.corp@lecroy.com, Internet: www.lecroy.com

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Once a nonlinear DC model has been verified for a transistor of interest, a good fit to the AC data can be achieved by adding the bond-wire and package parasitic effects.

Optimize LNA performance for CDMA applications

CODE-DIVISION-MULTIPLE-ACCESS (CDMA) communication systems employ sophisticated access techniques and power control to allow multiple users to function within relatively wideband channels, even in the presence of interference. For CDMA systems to work properly, however, requires extremely linear low-noise amplifiers (LNAs) and power amplifiers (PAs). Fortunately, Application Note AN1039 from California Eastern Laboratories (Santa Clara, CA) explains how to use the latest computer-simulation tools from Xpedion Design Systems (Milpitas, CA) to achieve optimal performance of LNAs used for CDMA systems.

California Eastern Laboratories develops its own nonlinear models based on internal characterization of its active devices. The choice of model is determined by evaluating the DC characteristics of a given device and comparing these measured characteristics to the characteristics of a nonlinear model. Once a DC model has been verified, a good fit to the AC data can be achieved by adding the bond-wire and package parasitic effects.

The application note shows how to use series feedback techniques, along with predictions of amplifier behavior from the nonlinear simulator, to improve the performance of the LNA. Inductive feedback is introduced on the source of the active device in order to maintain the lowest possible noise figure. The inductive feedback improves the stability of the amplifier as well as its linearity, while actually improving the noise figure by 0.001 dB at 1900 MHz.

The CAE software allows predictions of adjacent-channel-power-ratio (ACPR) values for the amplifier, as a function of different input power levels. The LNA is based on the company's model NE38018 GaAs heterojunction field-effect transistor (HJFET). For more, download the note from the company's website.

California Eastern Laboratories, 4590 Patrick Henry Dr, Santa Clara, CA 95054-1817; (408) 988-3500, FAX: (408) 988-0279, Internet: www.cel.com.

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cover story

Coaxial Tuners Control Impedances To 65 GHz

High-power harmonic load-pull tuners complement a line of coaxial millimeter-wave impedance tuners capable of measurements from 10 through 65 GHz.

JACK BROWNE
Publisher/Editor

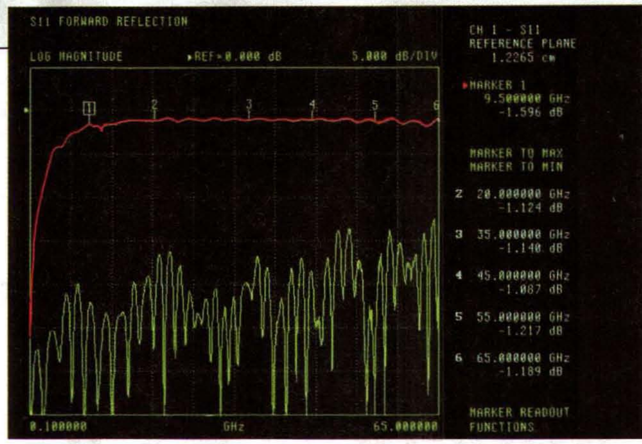
Device characterization at precisely controlled source and load impedances provides insights into the nonlinear behavior of both low-noise and power transistors. For transistors used in wireless amplifiers, this capability can reveal the impedance values needed for optimum linearity and highest efficiency, for example.

Having continuous bandwidth from 10 to 65 GHz allows a wideband look at transistor behavior. Having independent control over impedances at fundamental, second-harmonic, and third-harmonic frequencies makes it possible to evaluate and optimize nonlinear transistors and the effects of harmonic terminations. Fortunately, with the introduction of CCMT-6510 65-GHz coaxial tuner and a line of biharmonic combination tuners from Focus Microwaves (Dollard des Ormeaux, Quebec, Canada), engineers can now learn about device characteristics not apparent from even the best models.

The CCMT-6510 coaxial millimeter-wave tuner **(Fig. 1)** provides a minimum VSWR control range of 10.0:1 (and typically 15.0:1) at frequencies from 10 to 65 GHz. It offers better than 40-dB repeatability with fine stepper-motor-driven control of phase. The phase tuning resolution is 0.076 deg./step at 10 GHz and 0.49 deg./step at 65 GHz. The CCMT-6510 offers 7 million tunable points at 10 GHz and 1.1 million tunable points at 65 GHz.

1. Model CMT-6510 is a coaxial programmable tuner capable of providing precise control of impedance over a frequency range of 10 to 65 GHz.

The CCMT-6510 utilizes the coaxial 1.85-mm V-connector for continuous frequency coverage, in comparison to a waveguide tuner, which is restricted to waveguide-band frequency coverage, such as



2. The measured S_{11} forward reflection for the CMT-6510 programmable tuner shows excellent performance at marker frequencies from 9.5 to 65 GHz.

33 to 50 GHz or 50 to 75 GHz. Although limited in power-handling capability compared to a waveguide tuner, the continuous bandwidth of the CCMT-6510 allows harmonic tuning at precisely controlled impedance/phase states. The use of coaxial lines also allows DC bias to be passed along to an active device under test (DUT), such as a transistor or amplifier.

The CCMT-6510 makes use of a high-quality-factor (high-Q) resonator or probe that slides along a low-loss transmission line, under the control of a programmable stepper motor, to achieve different impedance (VSWR) states. The tuner achieves a reflection factor or gamma of about 0.9 (a gamma = 1 would represent total reflection, with no power delivered to the load) due to small losses in the transmission line and the probe, which is equivalent to a VSWR of typically about 15.0:1. The tuning resolution of the CCMT-6510 is simply the smallest possible movement offered by the stepper motor, which is about 3 μm.

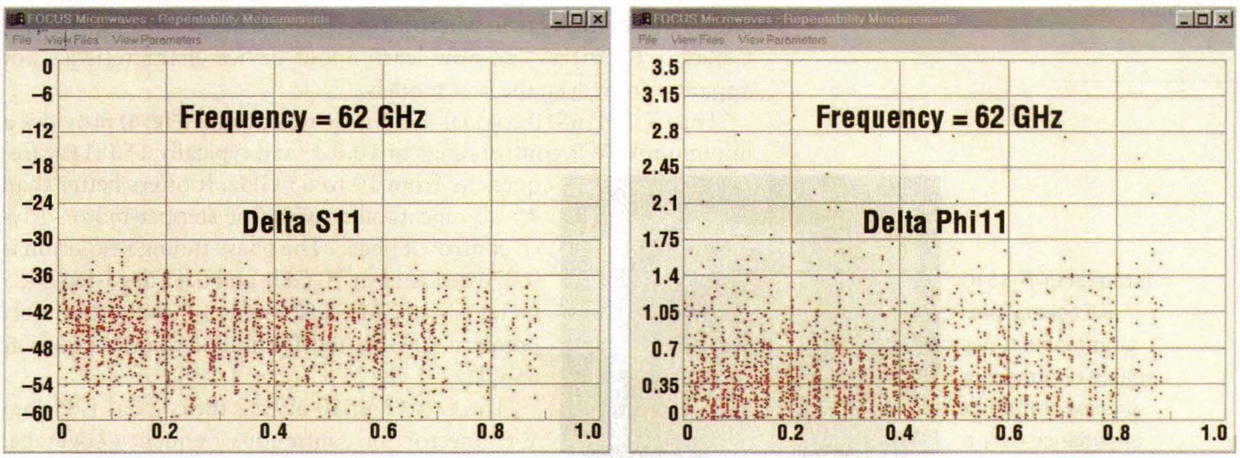
The CCMT-6510 probe is calibrated on a vector-network analyzer (VNA) at any number of frequencies in a sweep or list mode. The user can select the number of calibration points from 100 to 800. The measurement software interpolates with better than 40-dB accuracy to millions of tuning points. The calibration per frequency requires about 4 minutes per frequency. The end result of the precision calibration is a tuning range that is accurate and predictable, as evidenced by measurements of S_{11} forward reflection across the full tuning range **(Fig. 2)**. The repeatability of the CCMT-6510 is also outstanding, regardless of measurement power level **(Fig. 3)**.

The CCMT-6510 coaxial millimeter-wave impedance tuner, which is ideal for noise and load-pull testing, is supported by a 65-GHz through-reflect-line (TRL) calibration kit for proper setup with a coaxial millimeter-wave VNA from Agilent Technologies (Santa Rosa, CA) or Anritsu Co. (Morgan Hill, CA). The calibration kit includes a delay line, precision shorts, a 50-Ω line, and loads. In addition, the computer-controlled-microwave-tuner (CCMT) software allows operators to define their own instrument drivers. As a result, test equipment associated with the CCMT-6510, such as signal generators and VNAs, can be controlled from a personal computer (PC) running the CCMT software.

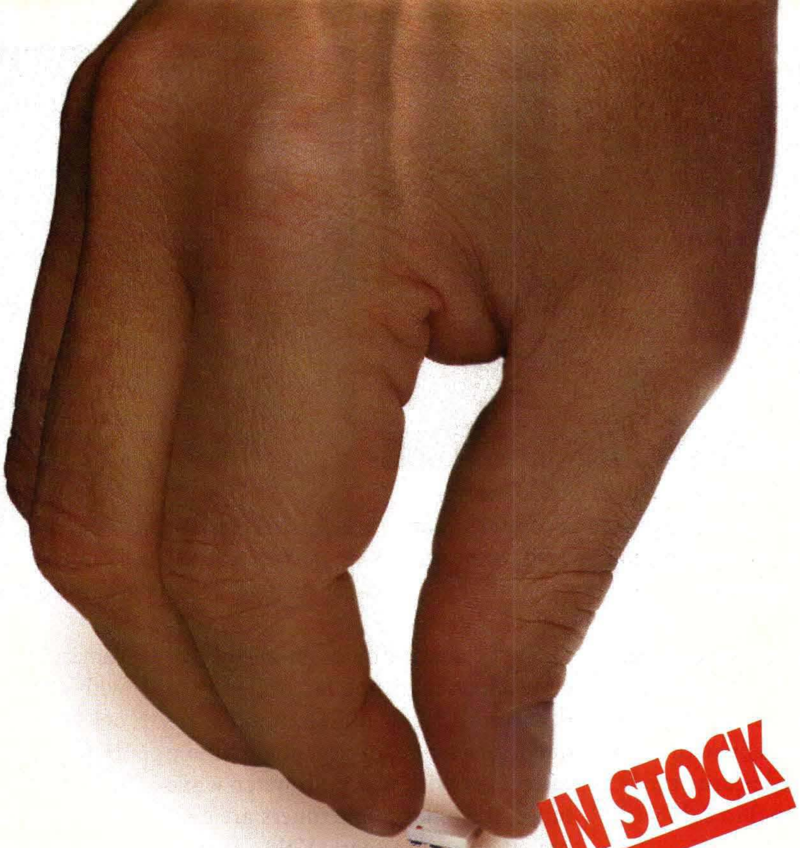
Harmonic Tuning

The biharmonic combination tuners are available for testing from S to K band. The tuners contain multiple probes or tuning slugs to control the impedance not only at the fundamental frequency, but also at the second- and third-harmonic frequencies. The probes are sliding resonant circuits connected in parallel to a low-loss transmission line. Depending upon the Class of bias (A, B, C, etc.), harmonics may have some effect on the behavior of a DUT. A biharmonic combination tuner allows independent impedance tuning at all three frequencies, allowing characterization as a function of three different impedance states.

For example, short circuits at second- and third-harmonic frequencies with the right phase at the output of a transistor in saturation can improve its gain and power-added efficiency (PAE). In addition, a short circuit at the second- and third-harmonic frequencies with the right phase at the input of a transistor can improve the device's linearity. Harmonic tuning has the maximum effect



3. The repeatability of the CMT-6510's impedance points is shown here for measurements of ΔS_{11} (left) and $\Delta \phi_{11}$ (right).



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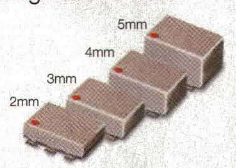

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ADEX-10L	+4	10-1000	7.2	60	16	3	2.95
ADE-1	+7	0.5-500	5.0	55	15	4	1.99▲
ADE-1ASK	+7	2-600	5.3	50	16	3	3.95
ADE-2	+7	5-1000	6.67	47	20	3	1.99▲
ADE-2ASK	+7	1-1000	5.4	45	12	3	4.25
ADE-6	+7	0.05-250	4.6	40	10	5	4.95
ADEX-10	+7	10-1000	6.8	60	16	3	2.95
ADE-12	+7	50-1000	7.0	35	17	2	2.95
ADE-4	+7	200-1000	6.8	53	15	3	4.25
ADE-14	+7	800-1000	7.4	32	17	2	3.25
ADE-901	+7	800-1000	5.9	32	13	3	2.95
ADE-5	+7	5-1500	6.6	40	15	3	3.45
ADE-5X	+7	5-1500	6.2	33	8	3	2.95
ADE-13	+7	50-1600	8.1	40	11	2	3.10
ADE-11X	+7	10-2000	7.1	36	9	3	1.99▲
ADE-20	+7	1500-2000	5.4	31	14	3	4.95
ADE-18	+7	1700-2500	4.9	27	10	3	3.45
ADE-3GL	+7	2100-2600	6.0	34	17	2	4.95
ADE-3G	+7	2300-2700	5.6	36	13	3	3.45
ADE-28	+7	1500-2800	5.1	30	8	3	5.95
ADE-30	+7	200-3000	4.5	35	14	3	6.95
ADE-32	+7	2500-3200	5.4	29	15	3	6.95
ADE-35	+7	1600-3500	6.3	25	11	3	4.95
ADE-18W	+7	1750-3500	5.4	33	11	3	3.95
ADE-30W	+7	300-4000	6.8	35	12	3	8.95
ADE-1LH	+10	0.5-500	5.0	55	15	4	2.99
ADE-1LHW	+10	2-750	5.3	52	15	3	4.95
ADE-1MH	+13	2-500	5.2	50	17	3	5.95
ADE-1MHW	+13	0.5-600	5.2	53	17	4	6.45
ADE-10MH	+13	800-1000	7.0	34	26	4	6.95
ADE-12MH	+13	10-1200	6.3	45	22	3	6.45
ADE-25MH	+13	5-2500	6.9	34	18	3	6.95
ADE-35MH	+13	5-3500	6.9	33	18	3	9.95
ADE-42MH	+13	5-4200	7.5	29	17	3	14.95
ADE-1H	+17	0.5-500	5.3	52	23	4	4.95
ADE-1HW	+17	5-750	6.0	48	26	3	6.45
ADEX-10H	+17	10-1000	7.0	55	22	3	3.45
ADE-10H	+17	400-1000	7.0	39	30	3	7.95
ADE-12H	+17	500-1200	6.7	34	28	3	8.95
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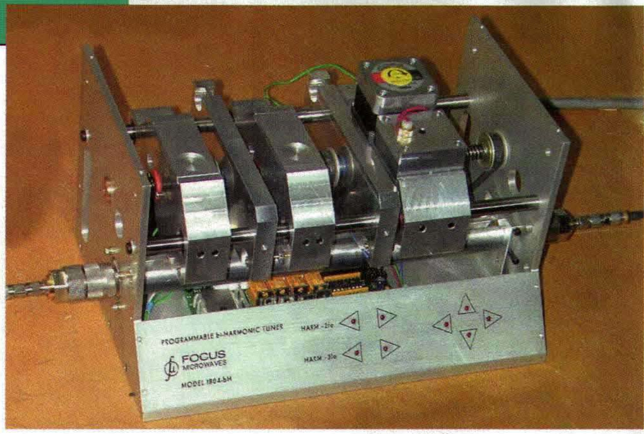
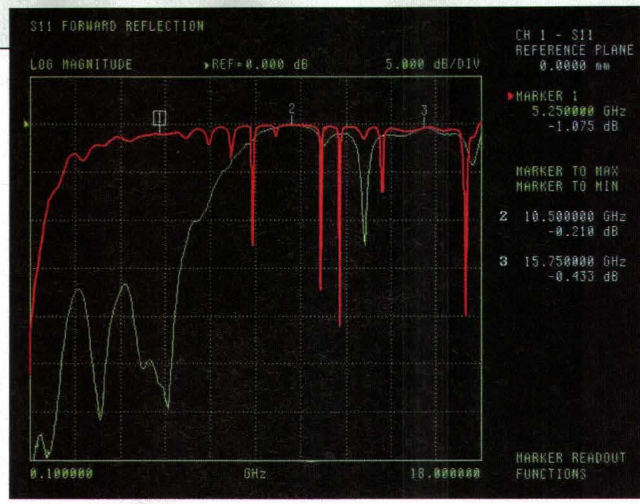


4. **This cover-off view of the 1804-bH tuner shows the resonator assemblies and stepper motor used to control a wide range of impedances at the fundamental, second-harmonic, and third-harmonic frequencies.**



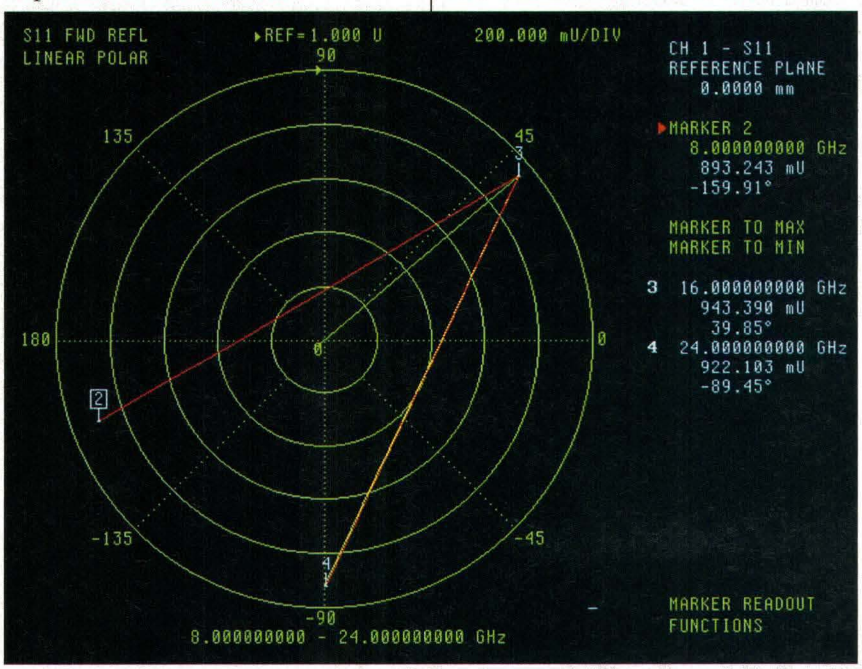
5. **The measured S_{11} performance of the 1804-bH biharmonic combo tuner shows the low-loss performance of the instrument.**

when the DUT is in saturation and generating high levels of harmonics. A device's PAE can be increased by as much as 10 to 35 percent with load harmonic tuning, while linearity can be improved by as much as 3 to 8 dB with source harmonic tuning.

The effects of harmonic tuning depend on the type of transistor, the power-saturation level, the frequency, and the bias conditions. Because of these variables, it is almost impossible to create an accurate nonlinear device model to describe the harmonic behavior of a transistor, and harmonic load-pull testing is required to understand a device's behavior under a specific set of conditions.

The biharmonic tuners are able to generate a high reflection factor (between 0.95 and 0.99) at both harmonic frequencies over a 360-deg. phase tuning range. As with the millimeter-wave tuner, the biharmonic tuners are calibrated on an automatic VNA. At each position of the fundamental set of resonators, all user-defined impedances of the harmonic resonators are calibrated. After this, second-order polynomial algorithms interpolate between the calibrated points to provide phase errors of typically as low as 0.1 to 0.6 deg. and amplitude errors between –40 and –60 dB.

Model 2608-bH is an example of the new biharmonic tuner line. It covers a fundamental/harmonic range of 8 to 26.5 GHz, with a nominal fundamental frequency of 8 GHz, second-harmonic frequency of 16 GHz, and third-harmonic frequency of 24 GHz. Model 1804-bH has a fundamental/harmonic frequency range of 4 to 18 GHz. With a nominal fundamental frequency of 5.25 GHz, the second-harmonic frequency is 10.5 GHz and the third-harmonic frequency is 15.75 GHz. The multiple-resonator, stepper-motor-driven tuner **(Fig. 4)** can be controlled or programmed by means of a PC program. Harmonic load-pull software controls the tuners for independent tuning at fundamental and harmonic frequencies.



6. **This linear polar plot of the 2608-bH combo tuner demonstrates the precise and independent tuning control over the impedances at the harmonic frequencies.**

In a measure of frequency response (S_{11} forward reflection), the 1804-bH shows levels at are down by –0.43 dB or better at the second- and third-harmonic frequencies from a nominal –dB reference level **(Fig. 5)**. The independent tuning control of the 1804-bH is apparent from a linear polar plot at the fundamental and harmonic frequencies **(Fig. 6)**.

The electromechanical biharmonic tuners are compact and sufficiently light in weight for use in on-wafer harmonic load-pull test setups, with installation close to the wafer under test. In addition to the frequencies noted, the two models above can be tuned to other frequencies by replacing the harmonic resonators. **Focus Microwaves, Inc.,** 1603 St. Regis, Dollard-des-Ormeaux, Quebec, Canada H9B 3H7; (514) 683-4554, FAX: (514) 684-8581, e-mail: info@focus-microwaves.com, Internet: www.focus-microwaves.com.

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Top Products of 2002

The list for 2002 offers a comprehensive mix of hardware, software, and test instruments, with technologies supporting architectures ranging from baseband to optical.

JACK BROWNE
Publisher/Editor

Technology advances even during difficult years, as evidenced by an impressive collection of new products making up the Top Products of 2002. Selected by the editors of Microwaves & RF, the top 13 products of 2002 (see table) represent the diversity of technologies employed by this magazine's readers, from software to hardware, and from RF and baseband through millimeter-wave frequencies and optical signals. The list is a true "boiling pot" of manufacturers, a mixture of the old and the new, and the large and the small.

Among the smallest of the Top Products comes from north of the border, in the form of the SE4100 Global Positioning System receiver (Rx) integrated circuit (IC) from SiGe Semiconductor (Ottawa, Ontario, Canada). Based on silicon-germanium (SiGe) process technology, IC integrates an intermediate-frequency (IF) filter, voltage-controlled oscillator (VCO), oscillator tank circuitry, low-noise amplifier (LNA), phase-locked loop (PLL), and crystal oscillator within a package measuring just 4 × 4 mm. The first product in the company's line of PointCharger Global Positioning System (GPS) devices, the chip draws less than 10-mA current from a +2.7-VDC supply. When coupled with a commercial baseband IC from ST Microelectronics, the chip forms a GPS Rx solution that consumes less than 120 mW of power.

The "other" GPS Rx on the list is from Valence Semiconductor (Irvine, CA), but is based on complementary-metal-oxide-semiconductor (CMOS) process technology. The company's VS7001 Rx IC, which is designed for supply voltages from +2.3 to +3.6 VDC, consumes less than 30-mW power at +2.3 VDC.

Maxim Integrated Circuits (Sunnyvale, CA) contributed their MAX5886-MAX5888 line of low-power digital-to-analog converters (DACs) to the list. Designed for multicarrier signal generation in cellular base stations, the DACs offer 14-b typical resolution at sampling rates to 500 MSamples/s with noise levels to –160 dBc/Hz and outstanding dynamic-range performance.

Analog Devices, Inc. (Wilmington, MA) continued to advance the state of direct-digital-synthesis (DDS) technology with their 9954 DDS IC. It consumes only 180-mW power when operating at an update rate of 400 MSamples/s. The IC features on-chip 1024 × 32 b random-access memory (RAM), an integral 14-b DAC, a PLL clock multiplier, an on-chip crystal oscillator, and a high-speed comparator. In spite of the integration, it is designed to operate on only +1.8 VDC. The DDS has a 32-b phase accumulator for tun-

ing resolution of 0.093 Hz with a 400-MHz clock. The 14-b DAC accounts for excellent spurious performance (narrowband performance as good as −85 dBc).

The FE-205A, FE-405A, and FE-505A line of digital oven-controlled crystal oscillators (DOCXOs) from FEI Communications (Mitchell Field, NY) made use of DDS technology to provide correction to the output frequencies in order to achieve output frequency accuracy rivaling that of more expensive rubidium clock oscillators. Available at standard frequencies of 10 and 15 MHz, and custom frequencies from 5 through 25 MHz, the sources feature a double-oven structure and stress-compensated (SC) cut crystals, the DDS circuitry allows the OCXOs to achieve temperature stability of better than 1×10^{-10} at temperatures from −40 to +75°C. and typical aging of 5×10^{-11}. The phase noise is −145 dBc/Hz offset 10 kHz from the carrier.

RF Micro Devices (Greensboro, NC) entered the fast-growing wireless-local-area-network (WLAN) market with a competitive chip set for the IEEE 802.11b standard at 2.4 GHz. The chip set includes an LNA/mixer, transceiver, transmit power amplifier (PA), and baseband processor. The processor, of course, represents a bold introduction for a company formerly associated with only RF technologies. Yet, coupled with the other three devices, it forms part of a complete WLAN solution that is supported with reference designs and software.

The Trinity chip set from XtremeSpectrum (Vienna, VA) marked the first commercial product based on ultrawideband (UWB) technology. Rather than using a modulated carrier to wirelessly transfer information, UWB technology relies on a series of short pulses spread over a relatively wide bandwidth. The four ICs, which include a medium-access controller (MAC), a baseband controller, a transceiver, and an LNA, can transfer data rates as high as 100 Mb/s over short distances while requiring less than 200 mW of power. The first three chips are based on a CMOS process, while the LNA is fabricated with SiGe.

Several software packages graced the 2002 list, including Applied Wave Research's (AWR) Visual System Simulator (VSS2002) 2002 and Version 2.0 of Computer Simulation Technology's CST Design Studio. The VSS2002 program is a true system simulator, allowing users to quickly create block diagrams of complex systems. A major advance in the Advanced Communication Links Analysis and Design Environment (ACOLADE) simulation technology acquired by AWR from ICUCOM (Troy, NY), the program features more than 230 core elements and mathematical primitive elements that can be used in creating and defining system func-

tions. VSS2002 offers models for encoders/decoders, filters, modulators, demodulators and comprehensive libraries for Enhanced Data-Rate for GSM Evolution (EDGE), code-division-multiple-access (CDMA), and WLAN systems.

Version 2.0 of the CST Design Studio, which is based on an open design environment, breaks large problems into a series of smaller-but-related problems. The software allows an electromagnetic (EM)-based system to be broken down into smaller components or blocks, each described by its own generalized S-parameter matrix. The software uses Visual Basic for Applications (VBA) macro language to simplify customization. Its component-object-model (COM) interface enables seamless integration of a variety of other software tools, including Matlab and MS Excel.

Several oscilloscopes made the 2002 list, including the WaveMaster 8500 digital storage oscilloscope (DSO) from LeCroy Corp. (Chestnut Ridge, NY) and the 4-GHz 54854A and 6-GHz 54855A Infinium oscilloscopes and InfiniiMax probe system from Agilent Technologies (Santa Rosa, CA). The WaveMaster employs the X-Stream architecture to eliminate trade-offs between fast processing the memory requirements for storing long records. Based on the company's proprietary SiGe front-end ICs, the scope can digital signals at 10 GSamples/s on four channels, then send the data to a CMOS acquisition memory that can store as many as 48 million points of acquired data. The effective sampling rate can be increased to 20 GSamples/s when only two channels are used.

The Infinium scopes each deliver sampling rates to 20 Gb/s on four independent measurement channels, with generous acquisition memories, but it is

Top Products at a glance (listed alphabetically)
1. Agilent Technologies' 54854A/54855A Infinium Scopes and InfiniiMax probes (October Cover, p. 102)
2. Analog Devices' December Cover
3. Applied Wave Research's Visual System Simulator 2002 (February Cover, p. 116)
4. Computer Access Technology's Merlin Mobile Bluetooth protocol analyzer (October, p. 107)
5. Communications Techniques' CR-40 clock recovery unit (April, p. 94).
6. Computer Simulation Technology's CST Design Studio, Version 2.0 (May Cover, p. 144)
7. ExtremeSpectrum's 100-Mb/s ultrawideband (UWB) Trinity chip set (July, p. 98)
8. Frequency Electronics' FE-205A, FE-405A, and FE-505A digital oven-controlled crystal oscillators (DOCXOs) (March Cover, p. 100)
9. LeCroy Corp.'s Wavemaster 8500 Digital Storage Oscilloscope (May, p. 166)
10. Maxim Integrated Circuits' MAX5886-MAX5888 family of DACs (November Cover, p. 95).
11. RF Micro Devices' 802.11b WLAN chip set (August Cover, p. 102)
12. SiGe Semiconductor's SE4100 SiGe GPS receiver IC (October, p. 108)
13. Synergy Microwave's VCSO-based clock translators (September Cover, p. 110).
14. Valence Semiconductor's VS7001 CMOS GPS receiver IC (June, p. 108).

perhaps the probe system that is the news here. The probes incorporate extremely wideband amplifiers (3.5-, 5-,and 7-GHz bandwidths are currently available) to overcome the bandwidth-limiting effects of accessories, such as wireless extensions, added to the tip of a probe. As a result, these probes can provide true wideband responses through 7 GHz of bandwidth, without the limitations of conventional active probe systems.

One of the more interesting measurement tools introduced in 2002 came from Computer Access Technology Corp. (Santa Clara, CA), with the Merlin Mobile Bluetooth protocol analyzer. Designed for full-featured protocol analysis according to Version 1.1 of the Bluetooth standard, the entire instrument fits within a standard 16-b Type II PC card measuring just 5.3 × 2.1 × 0.4 in. (135 × 54 × 10.5 mm). The analyzer can capture and analyzer Bluetooth signals within a piconet, evaluating the baseband, LMP, L2CAP, SDP, RECOMM, TCS, and OBEX layers of the Bluetooth protocol stack. It also provides standard decoding functions for HDLC, PPP, BNEP, HID, and AT commands, and can create custom decoding functions. The Merlin Mobile protocol analyzer supports point-to-point and point-to-multipoint piconets, and allows time stamping of events with 100-ns resolution.

Two of the award winners were aimed at clock timing in high-speed optical circuits, the CR-40 clock-recovery unit (CRU) from Communication Techniques, Inc. (Whippany, NJ) for use in OC-768/STM-256 high-speed optical communications systems operating at 40 Gb/s, and the CTM-8-OCXX and CTS-8-OCXX series of clock translators from Synergy Microwave Corp. (Paterson, NJ). The CR-40 CRU is based on a high quality-factor (Q) single-pole dielectric-resonator filter with bandpass response centered at the clock frequency. Jitter generation for the CRU is less than 15 mUI root mean square (RMS), while the typical phase noise of a 39.813-GHz recovered clock signal is –74 dBc/Hz offset 10 kHz from the carrier.

Synergy's clock translators are based on the use of surface-acoustic-wave (SAW) technology within voltage-controlled SAW oscillators (VCSOs) to provide precise output clock frequencies with low phase noise when fed with different-frequency input signals. For example, the model CTS-C1-12 clock translator operates with an input frequency of 51.84 MHz and provides an output signal at the SONET frequency of 622.08 MHz. For an input signal at +10 dBm, the output signal level is +6 dBm. The output jitter is typically only 3 ps. The clock translators are available for use with single or multiple input signals (the S and M in the product codes). MRF

Tiny Quad Hybrid Spans 2 To 18 GHz

Multilayer technology yields a 3-dB coupler for applications in which wide instantaneous bandwidth, small size, and light weight are critical.

Reduced component size and weight pay tremendous dividends in systems requiring hundreds or thousands of components, such as phased-array radars. The QHD-3C-10G quadrature hybrid coupler from Merrimac Industries (West Caldwell, NJ) is an example of a traditionally large component that has been scaled to a fraction the size of conventional couplers, with performance from 2 to 18 GHz that is comparable to its much-larger counterparts.

ROCCO DELILLO
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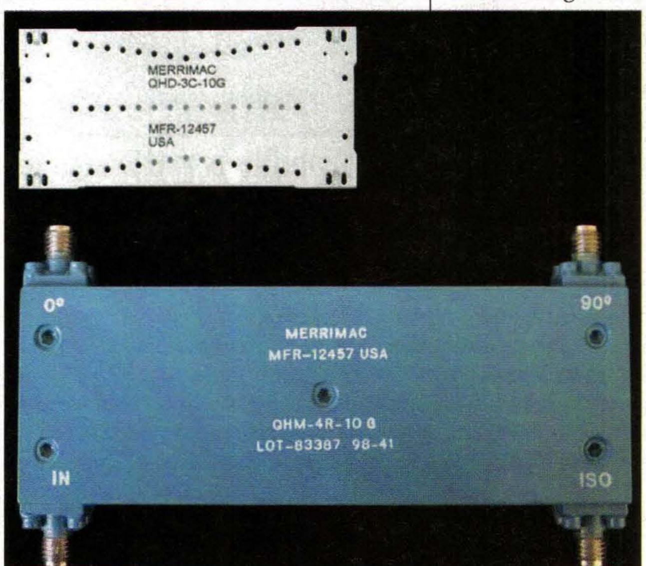
The QHD-3C-10G is fabricated with the company's proprietary Multi-Mix manufacturing process, in which fluoropolymer composite substrates are fusion-bonded to form a multilayer structure. A monolithic Multi-Mix structure can contain both active components, such as diodes, transistors, and MMICs, and passive components, such as etched resistors, circuit patterns, plated-through viaholes; no additional packaging is required. The ceramic-filled polytetrafluoroethylene (PTFE) dielectric materials employed in the design are compatible with popular substrates such as FR-4, G-10, and polyamide, and the "wrap-around" ground plane provides a high level of electromagnetic-interference (EMI) shielding.

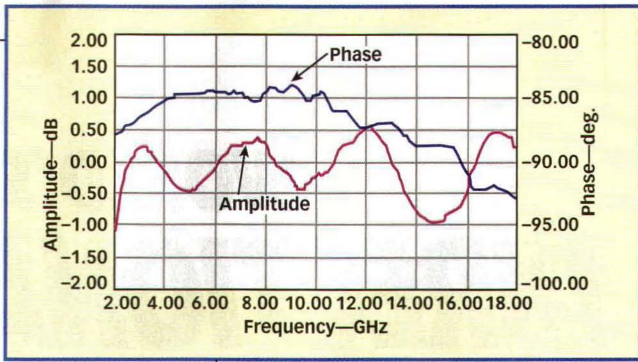


1. The QHD-3C-10G 2-to-18-GHz hybrid coupler leverages Multi-Mix multilayer circuit technology to achieve small size and weight without sacrificing power-handling capability.

Multi-Mix devices are typically only a fraction of the size of components fabricated with conventional stripline or microstrip approaches. The QHD-3C-10G **(Fig. 1)** is a fraction of the size of one of the company's conventional microstrip designs. It is 95 percent smaller, measuring only 1.6 × 0.75 × 0.065 in.

(compared to 2.85 × 1.10 × 0.50 in. for the conventional coupler), and 95 percent lighter (0.13 oz. vs. 2.5 oz.), while being compatible with surface-mount manufacturing.

The QHD-3C-10G features insertion loss of 2 dB or less, isolation of at least 15 dB, VSWR at all ports of 1.5:1 or less, and an operating temperature range of –55 to +85°C. Despite its diminutive size, the coupler can handle CW input power to typically 25 W. It maintains excellent amplitude and phase balance **(Fig. 2)** of ±0.7 dB and ±8 deg., respectively, which makes it well suited for in-phase/quadrature (I/Q) networks, multicarrier power amplifiers (PAs), and other signal-distribution configurations.



2. The amplitude and phase balance of the QHD-3C-10G hybrid coupler make it suitable for use in I/Q networks and multicarrier power amplifiers (PAs).

The size and weight savings provided by the QHD-3C-10G can be expanded (while maintaining tight control over phase and amplitude) by stacking and interconnecting multiple units via transmission lines that traverse the Z axis between the units. In addition, the device can be integrated with other Multi-Mix components to form a module that provides several functions (such as beamforming networks and other complex signal-processing functions) in much less space than the discrete functions could otherwise be realized.

The QHD product family meets environmental screening requires per MIL-STD-202 for thermal shock, burn-in, acceleration, vibration, mechanical shock, moisture resistance, thermal cycling, and resistance to solder heat. In addition to the 2-to-18-GHz frequency range, the quadrature hybrid is available in bands between frequencies of 200 MHz and 40 GHz, and can be supplied on either tape and reel for surface mounting, or with a coplanar waveguide RF interface. It can also be designed to optimize various performance parameters, including phase and amplitude, isolation, and insertion loss. **Merrimac Industries, 41 Fairfield Pl., West Caldwell, NJ 07006; (888) 434-6636, FAX: (973) 882-5990, Internet: www.multi-mix.com.**

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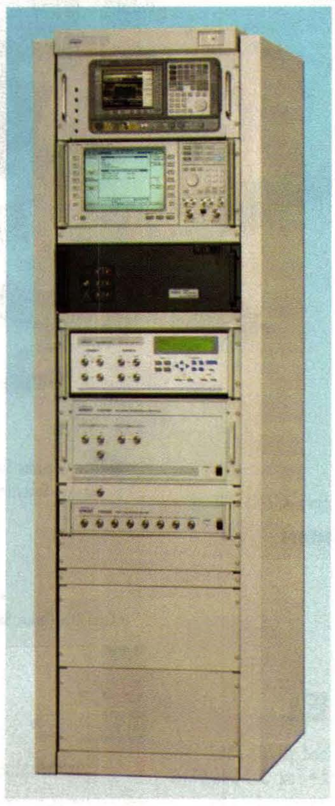
System Automates GSM/WCDMA Location-Capable Mobile Testing

This sophisticated test solution performs comprehensive testing on GSM and WCDMA mobile handsets employing wireless position-location technologies.

JACK BROWNE
Publisher/Editor

Position-location capabilities are being installed in both code-division-multiple-access (CDMA) and Global System for Mobile Communications (GSM) networks. In the US, these capabilities are mandated by such policies as the Federal Communications Commission's (FCC's) E911 Phase II. For manufacturers seeking to evaluate the performance of position-location functions in CDMA handsets, the CDMA Position Location Test System (PLTS) from Spirent Communications (Eatontown, NJ) has been available for about a year. The PLTS has recently been integrated with Spirent's C2K-ATS CDMA2000 Automatic Test system **(see figure)** to fully characterize the performance of CDMA handsets.

Handset manufacturers are now developing GSM and wideband CDMA (WCDMA) mobile devices that include position location. In the US, the driver is again E911 and in Europe a similar initiative (E112) will soon be requiring location capabilities to be included in handsets. Commercial location-based services (LBS) are the other big drivers of location technology, with market forecasts ranging from $10 billion to $100 billion by the end of this decade. For these handset manufacturers, and the operators that buy their products, Spirent is adding location capabilities to its recently announced U-ATS Universal Mobile Telecommunications System (UMTS) Automatic Test System.



Pictured here is Spirent's U-ATS UMTS Automatic Test System.

Like the integrated PLTS/C2K-ATS system, the U-ATS is intended to be a complete test bed for the evaluation of WCDMA mobile device performance. The system incorporates a commercially available one-box radio test set to supply the call processing required to execute a wide range of physical layer transmitter (Tx) and receiver (Rx) para-

metric tests. A new advanced WCDMA network emulator from Spirent will shortly add advanced protocol control and multi-sector Node B emulation. Rx performance is characterized under impaired downlink conditions created by an RF channel emulator and interference emulator. TestDrive test-application software automates all aspects of test execution, including test suites for 3GPP Terminal Conformance test specifications, such as 34.121.

A key handset-based location technology whose popularity is expected to grow for both GSM and WCDMA networks is Assisted GPS (A-GPS). With A-GPS, assistance data is sent through the Radio Access Network. The data includes ephemeris, clock information and differential corrections. Compared with unassisted GPS, A-GPS enhances accuracy, integrity, time-to-first-fix and increases battery life. Measurements are always made in the handset, although position can be calculated in the handset ("MS-based") or in a Serving Mobile Location Center [SMLC] ("MS-assisted"). Recent sensitivity-enhancement techniques now allow satisfactory indoor operation.

To test the performance of GSM and WCDMA handsets that employ this technology, Spirent is integrating its GSS5060 GPS simulator into U-ATS to provide signals from up to 12 Global Positioning System (GPS) satellites. The GSS5060 models the GPS constellation in real time, including atmospheric and multipath effects and terrain obscuration. A commercial SMLC will provide assistance data to the handset and, for MS-assisted handsets, calculate the handset's location. A unique "virtual receiver" capability in the GSS5060 allows the GPS constellation to be modeled at two different locations simultaneously, one for the GPS reference Rx and one for the handset. The GPS reference Rx is modeled in software and the output data passed directly to the SMLC.

In the US, GSM operators initially selected E-OTD as the location technology for their E911 Phase II implementations. In recent months, a series of announcements has left only one major GSM operator, T-Mobile, publicly committed to following through on E-OTD deployment. With its unique range of signal-generator platforms and system-integration expertise, Spirent is also well positioned to offer performance test solutions for E-OTD capable handsets. **Spirent Communications, 541 Industrial Way West, Eatontown, NJ 07724; (732) 544-8700, FAX: (732) 544-8347, Internet: www.spirentcom.com.**

Enter No. 54 at www.mwrf.com

Delay-By-Events Trigger Aids Pulsed Signal Analysis

This power-meter trigger circuit allows a specific pulse within a burst to be analyzed, even when its position in time within the pulse burst is highly variable.

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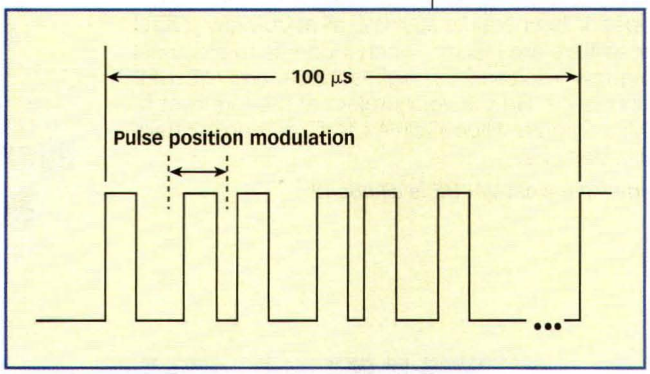
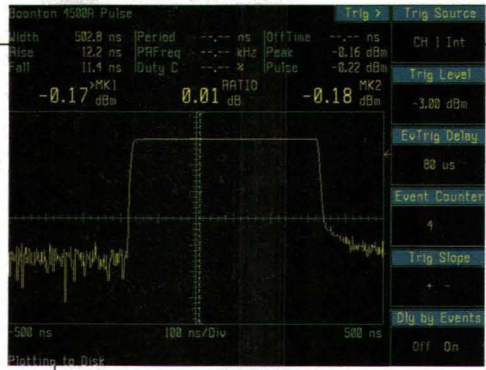
Measuring the peak and average power, rise and fall times, pulse widths, and delays of pulsed signals in ultrawideband (UWB), radar, remote sensing, digital wireless, and optical systems requires a peak power meter capable of synchronizing to a specific pulse within a burst of pulses. An option for the 4400A and 4500A series peak power meters from Boonton Electronics (Parsippany, NJ) simplifies these measurements, especially for systems employing pulse-position modulation (PPM), in which pulses are not symmetrically spaced but vary in their time relationship to each other.

In PPM, the delay of a pulse conveys information while the amplitude and pulse width are kept constant **(Fig. 1)**. The position of the pulses relative to each other is varied by each instantaneous sampled value of the modulating wave. Because of the constant amplitude and duration, transmitter requirements for PPM are fairly straightforward. The modulation format is highly efficient, and increasing employed in a variety of radar and communications systems. But evaluating PPM pulse bursts requires special tools, such as properly equipped peak power meter. Without the ability to synchronize to a specific pulse within the burst, the task is reduced to trial and error.

A typical measurement example shows why this is so. In this case, the signal to be measured is a group of six pulses each 1 µ wide, in a burst that repeats every 100 µs. The goal of the measurement is to trigger on every fourth pulse. If an edge trigger is used, the peak power meter will trigger on an edge, but not necessarily that of the fourth pulse. A standard edge-triggered power meter is unable to synchronize to any specific edge in the burst and also unable to isolate



1. In pulse position modulation (PPM), pulses are unevenly spaced in time.



2. The fourth pulse in a PPM burst was selected and captured by the delay-by-events trigger, which allows detailed analysis to be performed.

the fourth pulse in the burst.

By using the trigger holdoff capability of the 4400A/4500A meters, a period of time can be identified during which triggering will be inhibited (ideally slightly less the burst's cycle time). In this case, the peak power meter will lock onto the first edge of the pulse train. Hold-off can also be used in conjunction with trigger delay to view periods of time in a burst of pulses. Trigger delay is a time specified by the user that is offset from trigger event to the point when the data is captured. In this example, trigger delay would be set to position the fourth pulse in the center of the display. However, since the trigger is not locked onto the edge of the fourth pulse, it provides little benefit when evaluating PPM signals.

The optional delay-by-events-trigger capability solves this problem by combining trigger hold-off with an event counter to ensure that synchronization is achieved not just with the start of a pulse burst, but with any pulse up to 65,534 events afterward. This, in effect, eliminates synchronization problems associated with PPM as well as with time jitter. A user simply selects the trigger hold-off time and chooses a specific event to trigger on. The circuit counts the events and holds the trigger until the specified event count has been reached, even if this requires counting into subsequent bursts or the hold-off time has elapsed.

The user then has the ability to analyze the desired pulse in great detail. For example, the pulse rise and fall times can be controlled to minimize jitter, with the edges just fast enough to achieve low jitter but not so fast that they are out of band. In **Fig. 2**, the fourth pulse in the burst has been locked-on and the time scale has been changed to allow an accurate measurement of its rise and fall times to be made. The delay-by-events trigger option is available for all models of the 4400A and 4500A series meters, and can be added to instruments already in service. **Boonton Electronics (a Wireless Telecom Group Co.), 25 Eastmans Rd., Parsippany, NJ 07054; (973) 386-9696, FAX: (973) 386-9191, Internet: www.boonton.com.**
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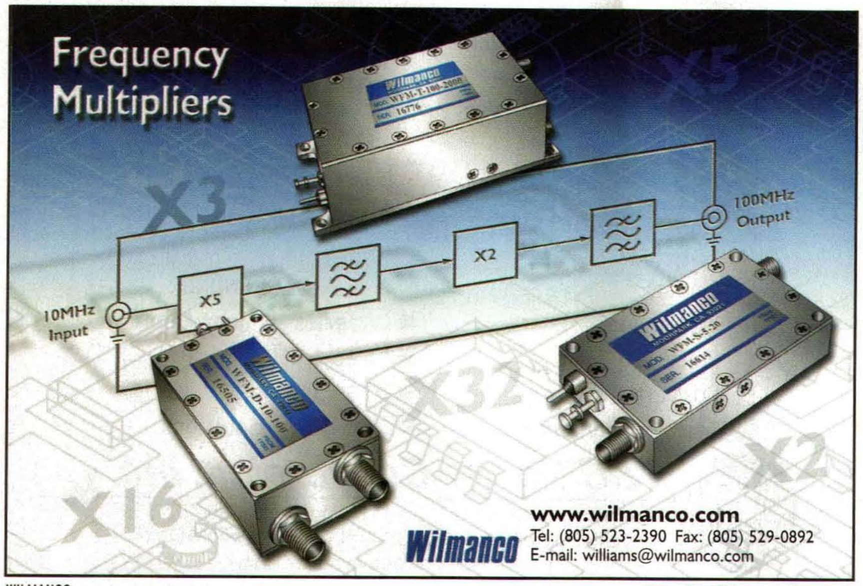

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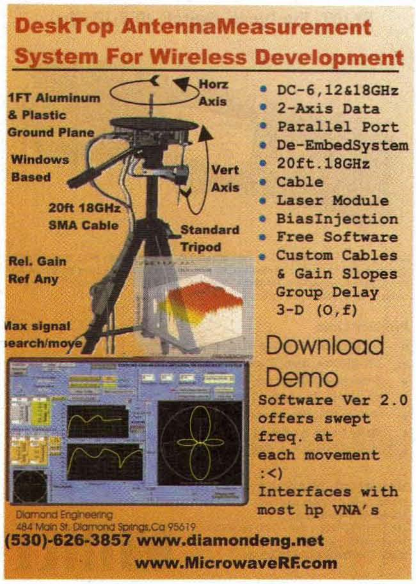

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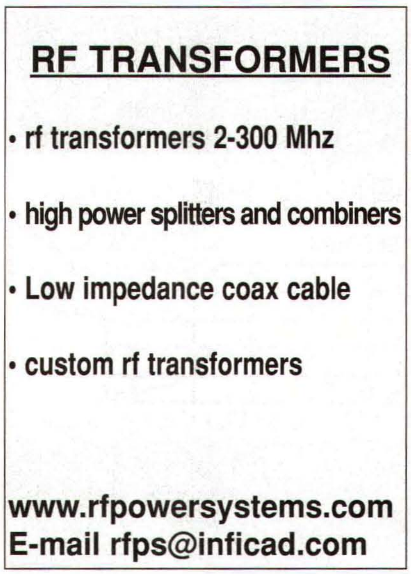

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looking back

JUST OVER TWENTY YEARS AGO, Howard King and Dr. Jimmy Wong of Aerospace Corp.'s Electronic Research Laboratory (El Segundo, CA) demonstrated the disc-o-cone wideband antenna with a reported 16-dB gain from 1.2 to 1.6 GHz. The antenna consisted of a disc on a rod in a conical horn.

next month

Microwaves & RF February Editorial Preview

Issue Theme: Computer-Aided Engineering

News

Last year at this time, the Visual System Simulator 2002 from Applied Wave Research (El Segundo, CA) created waves in the high-frequency industry by combining ease of use with a powerful block-diagram simulation engine. As time-to-market pressures have increased, more and more designers have learned to effectively use system simulators to understand the higher-level behavior of their designs. Following the issue theme, this Special Report will highlight commercially available system simulators from a variety of sources, including Ansoft, Agilent Technologies, and Elanix, and briefly discuss their user interfaces, analysis engines, and modeling approaches for those readers who may be considering adding a system-level simulator to their lineup of software tools.

Design Features

February's Design Features will also focus on software, with Jim Rautio of Sonnet Software leading off a strong lineup with his analysis of a 13.56-MHz RFID indictor using his company's electromagnetic (EM) simulation tools. Additional software articles will examine how to model antennas for Global Positioning System (GPS) receivers, how to model photonic-bandgap structures using a popular suite of programs, and how to reduce filter synthesis time with a powerful commercial simulator. Also, a pair of Design Features will explore design issues for high-volume RF test fixtures and how to simplify the design of LO drive circuitry through the use of integrated buffers/splitters.

Product Technology

The February Product Technology section will detail an advanced GPS chip set with outstanding sensitivity, fast acquisition times, and software that simplifies the integration of the ICs into wireless products, such as cellular telephones and PDAs. Additional Product Features will review a new line of low-cost, high-performance oscilloscopes, a set of low-cost broadband amplifiers for 40-Gb/s OC-768 applications, and a line of high-power RF amplifiers for base-station applications.

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